Testing the Strength Model of Self-Control: Does Willpower Resemble a Muscle?

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This work or any part thereof has not previously been presented in any form to the University or to any other body whether for the purposes of assessment, publication or for any other purpose (unless otherwise indicated). Save for any express acknowledgments, references and/or bibliographies cited in the work, I confirm that the intellectual content of the work is the result of my own efforts and of no other person.

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Abstract

The strength model of self-control predicts that when people exert self-control, they should show performance decrements on subsequent self-control tasks. However, it is possible that this pattern of behaviour is confined to specific experimental procedures, which amplifies the effect. The aims of this thesis are to; 1) test the strength model predictions in sport; and 2) examine emotion as a mediator of self-control performance effects.

Study 1 consisted of two experiments. Experiment 1 set out to demonstrate a pattern of resource depletion. Forty-three sport and exercise students performed either an incongruent (self-control depletion) or congruent (control) Stroop task before and after performing a virtual reality cycling task on an indoor cycling ergometer. Findings showed the depletion group performed worse on the second Stroop task than on their first task *or* than the control group. Experiment 2 sought to address some of the methodological concerns in Experiment 1, and examine emotion as a factor explaining performance. Forty-eight physically active participants followed the same experimental protocol, but with an additional iteration of both tasks. Results demonstrated that both cycling and Stroop task performance improved across time. In addition, participants reported feeling happier and more motivated during the second cycling task.

Study 2 provided a conceptual replication of Study 1, using different tests of self-control. Twenty-six university-level male soccer players either performed the Loughborough Soccer Passing Test (LSPT) with (self-control depletion) or without (control) an audio file simulating crowd noise, and then performed the wall squat muscle endurance test. The self-control depletion group reported feeling more anxious during the LSPT and performed worse than the controls on the wall squat.

Next, in Study 3, nineteen well-trained competitive endurance runners performed a self-paced 1600 m running trial and then ran a second trial either self-paced or with a pacemaker. The pacemaker had no significant effect on actual performance time but participants reported feeling more anxious beforehand and adopted a fast start strategy, whereas the self-paced group had a conservative pacing pattern. Study 4 showed that, for females, consuming a sports drink—as opposed to plain water—associated with better physical (high-intensity track running) and cognitive self-control (Stroop) performance. In addition, they appeared to be happier drinking water, and more anxious drinking the sports drink—an effect that diverged over the six weeks.

Study 5 examined the effects of three strategies—designed to increase or decrease the intensity of emotions—on emotion, pacing strategy and 1600 m performance. Results showed the intervention designed to decrease unpleasant emotions was associated with lower anxiety, higher calmness, a slower first 400 m, and more overall consistent pacing strategy. Study 6 examined the effects of imagery training on swimming tumble-turn performance. Findings showed no significant intervention effect, a result that goes against the proposed benefits of psychological skills training and runs counter to the predictions of the strength model.

Collectively, the evidence in the thesis provides limited support for the strength model. It is concluded that self-control performance does not inevitably deteriorate across self-control tasks where the individual is well-versed with the task demands, or where tasks are not physically strenuous enough to tax mental resources. In contrast, the explanation for performance deterioration across a series of novel tasks is likely to extend beyond that of a self-control resources perspective. Future research might profitably test this proposal.

Acknowledgments

I often wonder how I ended up at this point: I dropped psychology as an A-Level subject, and wanted to be an artist. Yet here I am putting the finishing touches to a thesis in Sport and Exercise Psychology. And so I would like to thank those who started me on this journey, but most importantly, those who ensured that I got this thesis written.

The ironic thing about studying self-control is that one invariably ends up procrastinating…a lot! Perhaps unsurprisingly, then, I also found it quite hard to counter the habit. Which brings me to thank Professor Andy Lane for never allowing the deadline to run away from me. Thanks, also, for being downright good fun to work with. I'm not sure many PhD students cycle to conferences with their supervisor or sign up to a marathon within a few months of starting!

I would also like to acknowledge and express my appreciation to Dr Tracey Devonport. Tracey; along with Andy, you supported my development as a researcher, and offered opportunities to apply theory in real-world contexts. I have you to thank for introducing me to Ron Allan at Tipton Tennis Academy. Working with the players, coaches and parents there during my final year was a definite highlight of the PhD. Like Andy, your supervision, friendship, guidance and support is truly valued. I genuinely feel excited and confident that this experience will serve me well in all my future endeavours.

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Contents

List of Tables

List of Figures

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Chapter 1: Introduction

1.1 Background

Humans experience desires in everyday life. Kept under control they can bring out the best in people, but when ignored they can lead people astray. How do people keep their desires in check, and to what extent do their desires conflict with other goals? The ability to override and restrain desires requires self-control. Because self-control is often influenced by what others—and society as a whole—considers being ideal standards and values, people are often tempted to steer behaviour towards the collective interest of others rather than their own long-term personal goals. By virtue, this should foster co-operation and social harmony (Baumeister & Exline, 1999). However, under some circumstances, people find it hard to know which course of action is the good and right one. Why then, should humans feel compelled to conform to normative standards of behaviour—especially when they feel low relatedness or belonging to certain groups, or lack the relevant standards?

Although self-control may exist to benefit society, it is also needed for the pursuit of enlightened self-interest (Baumeister, DeWall, Ciarocco, & Twenge, 2005; MacLean et al., 2014). Past work suggests that those who are good at using self-control are more likely to achieve their long-term goals. For example, they go on to live healthier lives (Moffitt et al., 2011), achieve greater academic success (Tangney, Boone, & Baumeister, 2004) and enjoy healthier, more satisfying relationships (Finkel & Campbell, 2001). Moreover, this ability can be traced from early childhood as a strong predictor of behaviour and success in later life (Berman et al., 2013; Kochanska, Coy, & Murray, 2001; Mischel, Shoda, & Rodriguez, 1989; Moffit et al., 2011; Rosenbaum, 1980; Waegeman, Declerck, Boone, Van Hecke, & Parizel, 2014). Such is the positive array of outcomes associated with having good self-control that learning self-control appears extremely worthwhile.

However, it is not always easy to modify behaviour or avoid certain situations—particularly if it requires deliberate effort, time and time again. Couple it with feeling tired or stressed, then summoning the energy to do something different becomes deeply unappealing. Unfortunately, people often lose this skirmish and fail at self-control: it is endemic of today's society. From poor dietary control (Johnson, Pratt, & Wardle, 2012) and overspending (Vohs & Faber, 2007) to alcohol abuse (Cook, Young, Taylor, & Bedford, 1998) and impulsive sexual behaviour (Gailliot & Baumeister, 2007), many personal and societal problems appear to involve a substantial component of deficient self-control.

If self-control is requisite for human survival and social interaction, then we have to ask how self-control is achieved. The answer is that self-control cannot be understood purely from an evolutionary perspective, but must also be explained as a pattern of behaviour that is repeated across different contexts, over time. At present, there is considerable debate over the mechanisms behind self-control failure and how such acts become a coherent pattern of behaviour. Is everyone vulnerable to lapses in self-regulation? Or are some people more prone to failure than others? In actuality, it is quite likely that individual differences interact with situational self-control inducements. Gaining a clearer understanding of self-control is therefore of interest to many areas of social science.

In 2003, eminent social psychologist Professor Roy Baumeister summarised the work from his laboratory to that point in time by stating: "All our findings suggest that it [self-control] operates like a muscle or a well of energy. It becomes depleted through use and takes time (and rest) to replenish itself" (p. 4). Yet, as eloquent as the analogy may sound, its plausibility warrants interrogation. Traditionally, the approach has been to assess self-control in well-controlled laboratory settings, often whilst participants perform relatively static, or immobile, novel tasks, in unpredictable environments. If Baumeister's extrapolations from laboratory-based findings are to transfer to explanations of behaviour in real-life settings then researchers must be confident that their methods provide some resemblance to the performances and contexts being simulated.

To test Baumeister's predictions, the early experimental methods used in this thesis intentionally followed those used previously. Typically, the ego depletion effect—a phenomenon describing work and/ or performance decrements following self-control exertion—is demonstrated using either a dual-task (i.e., two tasks are performed at the same time) or a sequential task design (i.e., a series of tasks are performed in quick succession). As there is strong meta-analytic support for empirical tests of the ego depletion effect (Hagger, Wood, Stiff, & Chatzisarantis, 2010), it seemed logical to start from this point. Thereafter, the approach was to keep with the focus on behaviour. Experimental protocols and assessment techniques were developed to address some of the methodological issues raised in previous work, and test hypotheses that run counter to Baumeister's account.

The domain of sport offers considerable promise for researchers seeking to overcome some of the above challenges, where performance protocols such as time trials provide the opportunity to detect small but meaningful changes in performance (Currell & Jeukendrup, 2008). In suggesting that laboratory studies often fail to capture behaviour relevant to the normal population, Walsh (2014) proposed that sport provides an opportunity to understand fast, stressful, consequential behaviours that occur in the real world. According to Walsh, with the exception of combat activity, sport is perhaps the brain's biggest challenge, requiring more cognitive skills than is often appreciated. This proposal echoes that of Kirschenbaum (1984) who had earlier championed the many benefits of juxtaposing sport psychology and the study of self-regulation. Both authors suggested that progress in this area has been relatively slow, possibly because of the attitudes scientists have towards sport and field-testing. Kirschenbaum suggested that "…perhaps the high degree of intrinsic interest many people associate with sports paradoxically diminishes its credibility among many "serious-minded" scientists." (p178). Similarly, Walsh suggested that cognitive neuroscientists would have to accept working in a "messy" field but the objective nature of sport would ensure work is accountable. Thus, not only does conducting research in this area have the potential to contribute to the research of self-control but also the behavioural approach to this work provides a logical extension of previous findings. Additionally, given the evidence that successful self-control associates with academic achievement (Duckworth & Seligman, 2005; Tangney et al., 2004), better physical health outcomes (Moffitt et al., 2011), and goal attainment (Zimmerman, 2000), the initial development and testing of the experiments was primarily undertaken using student-athletes.

1.2 Overview of Current Research Programme

The core of the thesis comprises four experimental studies. A further two studies, for which I am a fifth and third author respectively, supplement this work, and are presented in the appendices in their published format. Schimmack (2012) recently argued that there appears to be a tendency to believe that once an effect has been shown to be statistically significant, then its truth has been established. With such a view, it is pointless to run additional experiments with the same methods because nothing is gained. However, whilst laboratory-based tests suggest a strong average effect size for the ego depletion effect—and intuitively the idea that self-control is fatiguing makes sense—there is reason to be circumspect that it is a robust and reliable phenomenon. Until this can be ascertained then researchers should be cautious about interpreting the findings too broadly. This thesis will therefore be making a timely contribution to the understanding of positive psychology by generating more empirical research findings and evidence-based practice focused on positive health and well-being.

In Chapter 3, Study 1, “Task Familiarisation Cancels the Resource Depletion Effect: A Test of the Strength Model of Self-Control in Cycling”, consists of two experiments designed to test the hypothesis that self-control performance would deteriorate across tasks (ego depletion). Following the prototypical methods of investigation utilised by Baumeister and colleagues (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Gailliot et al., 2007; Muraven, Tice, & Baumeister, 1998), Experiment 1 used a sequential-task design. One task (virtual reality indoor cycling) was hypothesised as contextually relevant and thus meaningful for the participants; whilst a second task (Stroop task) had unknown personal meaning. Participants completed the following task sequence: 1) Stroop task; 2) Cycling task; and 3) Stroop task. Experiment 2 sought to strengthen the conclusions from Experiment 1 and address some of the methodological limitations. In addition, applying Beedie and Lane’s (2012) resource allocation model of self-control, self-reported emotions were measured pre- and post-cycling performance as a mechanism explaining Stroop task and cycling task performance. It was proposed that, following self-control exertion and appraisal of the situation, an emotional and motivational response would emerge. If this state indicates that performance is important, an increase in effort in order to improve performance should follow. If performance is perceived as unimportant or unattainable then the resulting state should signal a reduction in effort, or conservation of resources.

Implications for the ego depletion phenomenon are discussed. In Chapter 4, Study 2, “Simulated Crowd Noise during a Soccer Passing Test Impairs Subsequent Self-Control”, extends this line of investigation with a similar focus on conceptual and methodological issues. The primary aim of Study 2 was to further investigate the mechanisms behind performance on successive self-control tasks. By recruiting well-trained participants and using an open-ended performance task to assess volitional control, it was proposed that performance at Time 2 would be influenced by emotional and motivational states following performance at Time 1.

The next two chapters comprise experimental work conducted in the field. Study 3 (Chapter 5), “The Influence of a Pacemaker on Psychological Responses During a 1600 m Run”, investigated the efficacy of running with a pacemaker during a 1600 m time trial as a strategy to augment self-regulation. Athletic pacing represents a natural self-regulation paradigm, and could offer new insight into the role of reasoned-based and planned behaviour on the performance of behaviour. Participants were asked to run two consecutive 1600 m time-trials: a control group performed two consecutive self-paced trials whilst an experimental group performed the same initial self-paced trial as the first group, but ran the second trial with a pacemaker. It was hypothesised that a pacemaker would reduce self-regulation effort. Building from the previous study, participants completed self-report measures for emotions, as well as self-referenced items measuring goal confidence and difficulty, and performance.

The final study entitled, “Effects of Consuming a Sports Drink on Performance in a Series of Physical and Cognitive Self-Control Tasks”, was also conducted in the field, and is detailed in Chapter 6. The aim of Study 4 was to test the hypothesis that consuming a sports drink containing glucose would improve self-control performance. Crucially, the study was designed to reflect real-world athletics practices. In this study, a sports drink was administered to a group of amateur runners who performed a high-intensity interval running training session, comprising eight repetitions of 800 m, across a period of six weeks. Participants also completed Stroop tasks during each session and provided self-report data for changes in emotion.

Two additional published studies (5 and 6) supplemented the programme of research and appear in the Appendices (A and B) (Devonport, Lane, & Fullerton, 2015; Lane, Devonport, Friesen, Beedie, Fullerton, & Stanley, 2015). The final chapter brings the work together in a general discussion of findings and makes suggestions as to how the work could influence practice and inform future research priorities. Importantly, the chapter outlines the theoretical contribution this PhD has made to the field.

The following review of the literature discusses the theoretical and methodological underpinnings of the work conducted into self-control. A detailed account of the empirical work is appraised, with a focus on its application to sport.

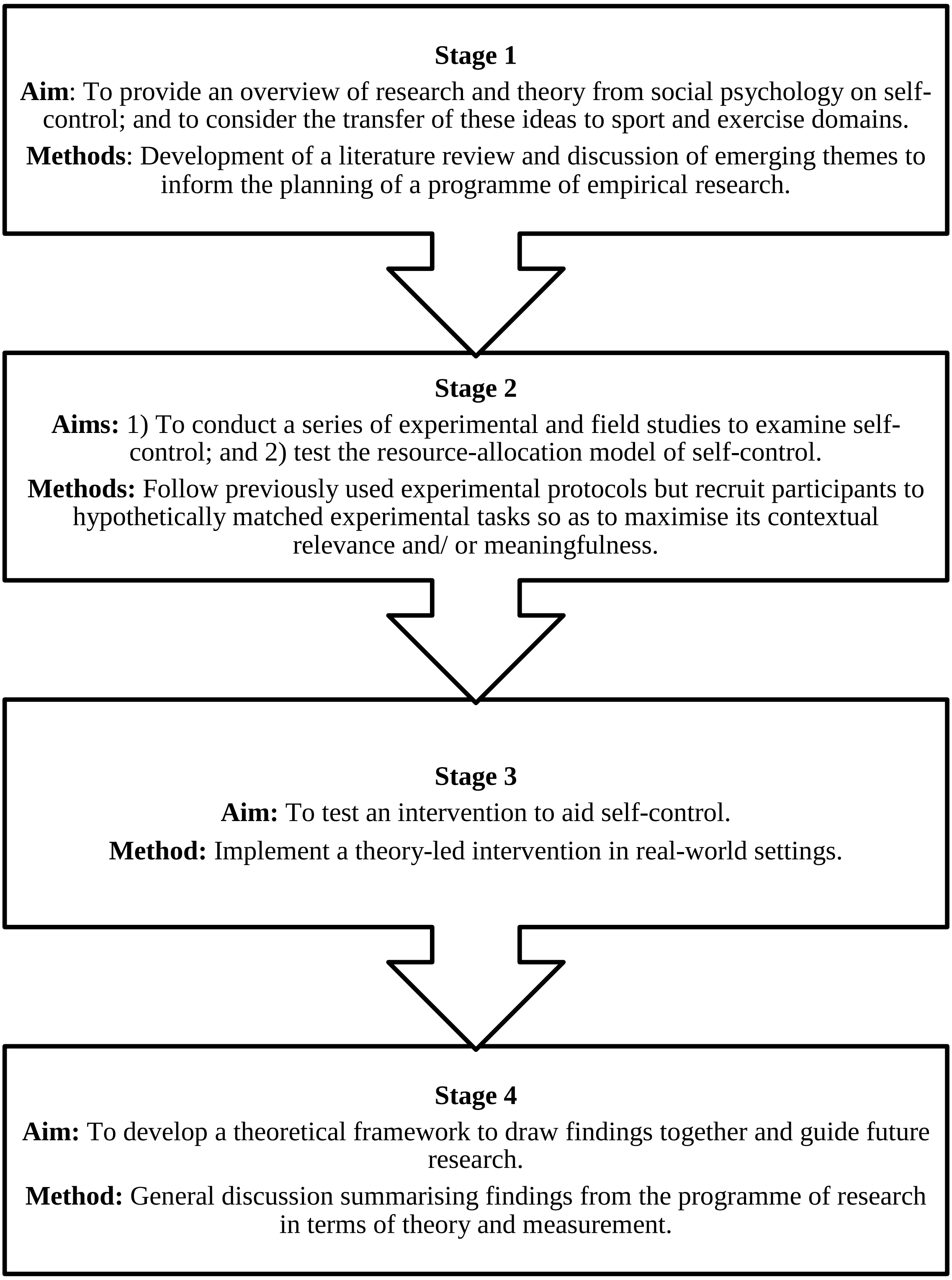


Figure 1. Stages of the PhD programme.

Chapter 2: Review of Literature

2.1 Abstract

Self-control operations appear to resemble a muscle. That is, self-control may consume resources that leave people with reduced capacity for further exertions until the resource is replenished. It has also been suggested that, just as a muscle grows stronger with exercise, practicing self-control can lead to long-term improvements in self-control. The present chapter critically examines the evidence that self-control ability is governed by a limited resource, and draws on multiple lines of evidence to consider whether the muscle analogy is an appropriate way to conceptualise self-control. This review specifically focuses on the strength model. It also evaluates the strength model alongside evidence testing similar hypotheses for sports performance. Convergent findings from these two perspectives suggest that self-control outcomes may rely on more than a limited resource. Several theoretical alternatives have been proposed, with researchers explaining self-control in terms of shifts in attention and motivation across tasks, implicit beliefs about self-control ability, costs and benefits associated with task performance, and resource allocation. The review concludes by synthesizing and integrating the findings, and indicates priorities for further research.

2.2 Introduction

The ability to plan and execute performance, make corrective adjustments to behaviour (e.g., modify skill execution or pacing strategy), resist temptation, manage emotions, elevate collective obligations above myopic self-interests, and persevere despite disappointment all constitute acts of self-control (or self-regulation) implicated in successful sports performance (Friesen, Devonport, Sellars, & Lane, 2013; Hardy, Jones, & Gould, 1996; Tamminen & Crocker, 2013). It therefore becomes clear as to why possessing a large capacity for self-control is beneficial for sports performance. However, altering the way one thinks, feels, or acts, before and during competition is not straightforward: it requires effortful deliberation, which may come at a cost (i.e., effort is expended at a cost to resources and performance is then compromised). Indeed, developing self-control strategies for use during competition has been highlighted as an essential requirement for sport psychology intervention work focused on attenuating effortful self-regulation. For example, Lahart et al. (2013) emphasised the importance of developing strategies that promote a strong belief that one can cope with the effects of extreme fatigue during multiday ultra-endurance events. Similarly, Devonport (2006) highlighted how developing emotional control strategies helped a martial arts performer enact an important competition strategy. However, for self-control interventions to work, it is important that researchers understand the mechanisms explaining the link between self-control and performance.

There is renewed interest in self-control, and the growing body of research linking it to success in a number of behavioural domains suggests debate in this area is healthy. The purpose of this chapter, therefore, is to consider evidence that suggests the ability to exert self-control is governed by the momentary availability of a limited resource. It examines the strength model of self-control and considers whether the conceptualisation is compatible with what is known about training adaptation, physical work capacity and sports performance. Although self-regulatory patterns have been proposed to mirror the decline in performance following physical exertion, some researchers argue it is unnecessary to imply that self-control shares the same resource mechanisms. In addition, the review considers alternative theoretical explanations. In particular, the resource allocation model of self-control is considered. To anticipate the conclusion of this review, a limited resource account is too simplistic. The review synthesises the existing evidence and paves the way for the experimental studies to advance self-control theory.

2.2.1 Definitions

Self-control is defined as the ability to intentionally alter the way one thinks, feels, or acts, in order to achieve a specific goal (Baumeister, 2002). The prototypical definition concerns impulsive behaviour; that being, inhibiting a normal, automatic pattern of behaviour. Many researchers view self-control processes under the rubric of self-regulation, which refers to the skills and processes involved with self-awareness, planning, maintaining, and changing behaviour (Heatherton, 2011). However, this broad perspective overlooks what some researchers consider distinctly different concepts. If one is to distinguish between the two, then, self-control suggests behaviour is associated with conscious thought and intent, whereas self-regulation implies that both conscious and non-conscious processes are involved. A prime example of self-regulation is that of homeostatic control, a concept which refers to the co-ordinated physiological processes that maintain a stable internal environment (Cannon, 1939). The activation of compensatory responses to achieve this steady state (e.g., sweating to reduce core body temperature in hot environments; Noakes et al., 1991) operates automatically. However, another example of self-regulation is pacing, which can be considered both a conscious and non-conscious strategy to attain a goal state (St Clair Gibson & Foster, 2007; St Clair Gibson, Lambert, Rauch, & Noakes, 2006; Tucker & Noakes, 2009). In this case, the individual will monitor his/ her current state against his/ her preferred state, and seek to resolve the discrepancy (e.g., slow down his/ her run speed). The prevailing research has used the terms interchangeably to describe how athletes behave in relation to goals, references, or states. Therefore, the perspective taken in this thesis is to treat the terms as synonymous.

2.3 The Strength Model of Self-Control

Models of self-control have emanated from a multitude of fields and ideas: from the early folk notion of willpower and Freud's energy-based account (1923/1961), to capacity-based models posited by researchers in the fields of information processing and cognitive psychology (e.g., Bandura, 1991; Grandjean, 1968; Kahneman, 1973, Meyer & Kieras, 1997; Robert & Hockey, 1997); to cybernetic ideas (Carver & Scheier, 1982, 2001; Powers, 1973; Wiener, 1961) and cognitive-emotional models (e.g., hot and cool systems; Metcalfe & Mischel, 1999); and more recently, muscular fatigue (e.g., the strength model; Baumeister, Vohs, & Tice, 2007). Of these, the strength model has emerged as the dominant theoretical account of self-control in contemporary psychology.

Baumeister and colleagues' perspective offers some bold proposals. First, after one difficult attempt at self-control, subsequent attempts at self-control should be more likely to fail (Baumeister, Bratslavsky, Muraven, & Tice, 1998). Second, directing one's self-control efforts towards one goal should diminish the resources available for self-control in any other behavioural sphere (e.g., emotion regulation led to a drop in physical stamina; Muraven, Tice, & Baumeister, 1998). Third, the decrease in self-control strength is presumably not permanent: People normally regain their lost strength, provided that conditions are favourable. For example, inducing positive emotion (Tice, Baumeister, Schmueli, & Muraven, 2007) or providing motivational incentives (Muraven & Slessareva, 2003) may encourage the individual to invest effort to try and regain self-control. Fourth, if self-control resembles a muscle, then frequent exercise of self-control followed by the opportunity for full rest and replenishment may gradually increase the individual's self-control strength (Baumeister, Gailliot, DeWall, & Oaten, 2006). Last, there are likely to be substantial individual differences in the basic capacity for self-control. In other words, some people may innately have a larger reserve of self-control strength than others (Tangney, Baumeister, & Boone, 2004). The next section considers the empirical evidence for these predictions, as well as integrating perspectives from sport and exercise science.

2.3.1 The Ego Depletion Effect

Upon reviewing the results of their laboratory tests of self-control, Baumeister et al. (1994) speculated that the decline in performance across tasks resembles the pattern of muscular fatigue. Until that point the notion that some sort of energy, akin to a loss of strength, was depleted following self-control had remained largely untouched since Freud theorised that the self or ego’s mental activities depended on the transfer of energy. However, according to Baumeister et al. the results were suggestive of a common resource being depleted and warranted a re-visit of the idea that if self-control resembles a muscle then it must depend on some energetic resource. Thus, in homage to Freud, the authors coined the term *ego depletion* to reflect the pattern of behaviour associated with self-control failure.

In 2010, Hagger, Wood, Stiff, and Chatzisarantis meta-analysed 198 published tests of the ego depletion effect, concluding that the evidence was robust and replicable with a *moderate* effect size (d = 0.62; 95% CI: [0.57, 0.67]). Ego depletion studies have typically used dual-task (Baumeister et al., 1998; Finkel, Campbell, Brunell, Dalton, Scarbeck, & Chartrand, 2006; Muraven et al., 1998; Vohs et al., 2008) and sequential-task paradigms. In this experimental set-up, participants are randomly assigned to either a self-control or no-self-control condition. The self-control condition involves performing an experimental task that taxes self-control resources and should lead to ego depletion, whereas the control condition requires participants to perform a task with little or no conscious need for self-control. This is then followed by a second unrelated (i.e., different behavioural sphere) self-control task, which is the same for all participants. Depending on the availability of self-control strength following the first task (i.e., what is assumed to remain of the resource), performance on the second task should differ between the two groups.

The most frequently used self-control tasks include the Stroop task, designed to assess inhibitory control (Gailliot et al., 2007; Johns, Inzlicht, & Schmader, 2008; Muraven et al., 1998; Schmeichel, 2007); squeezing a handgrip dynamometer for as long as possible, to challenge physical stamina and volition (Baumeister et al, 1998; Burkley, 2008); and working on an unsolvable puzzle, a measure of persistence (Vohs et al., 2008). For example, Muraven et al. (1998) randomly assigned participants to regulate their emotions (either amplifying or suppressing their emotions) or not to regulate them (remain passive) while watching a sad, distressing video clip. Afterward, participants performed the handgrip task, with those who had been told to regulate their emotions in the first task quitting sooner than those who had not engaged in emotion regulation. Furthermore, this effect remained regardless of whether participants had tried to amplify or suppress their emotions.

More recently, self-control theory has attracted attention in the field of sport and exercise psychology (e.g., Dorris, Power, & Kenefick, 2012; Englert & Bertrams, 2012; Furley, Bertrams, Englert, & Delphia, 2013; Graham, Bray, & Martin Ginis, 2014; Martin Ginis & Bray, 2010; Wagstaff, 2014). As previously considered, the context of sport offers researchers the opportunity to conduct experimental work with outcome measures closely resembling those used to measure sports performance in the field. Hypothetically, this population should find experimental self-control tasks interesting and thus any findings generated should have greater external validity.

Englert and Bertrams (2012) conducted two studies to test their hypothesis that self-control strength would moderate the negative effect of anxiety on sports performance, using tasks that require selective attention [basketball free throwing and dart throwing]. In their first study, basketball players were asked to perform 10 free throws following a word transcription task. Before performing the free throws, the participants were told that their performance would be compared to their teammates and other clubs, and then subsequently asked to rate their anxiety levels. In agreement with their hypothesis, the results showed a significant difference in free throw performance between the depletion and non-depletion group. Participants who were assigned to the high-anxiety condition reported higher anxiety and performed worse. For the second study, participants followed the same protocol. This time, though, participants threw three darts—again under similar evaluative conditions to Study 1—with results showing a similar effect for high state anxiety on performance.

In an attempt to construe self-control failure at a neurophysiological level, Bray, Martin Ginis, Hicks, and Woodgate (2008) hypothesised that depletion increases neuromuscular activity. They argued that self-regulatory failure on the handgrip squeeze task under depletion conditions can be interpreted under the central fatigue hypothesis (Davis, 1995). McEwan, Martin Ginis, and Bray (2013) extended this line of research to skill-based tasks, by examining whether muscle activation could explain the link between ego depletion (Stroop task) and subsequent performance (dart-throwing ability: accuracy and reaction time). Although, as expected, the experimental group performed worse than the control group, there was no significant effect for muscle activity as a mechanism for performance deterioration.

Ego depletion effects have also been shown to negatively affect endurance performance. Unlike fine motor skills such as throwing or tossing, which require attentional and cognitive control to maximise accuracy and minimise errors, gross motor skills such as cycling and running require participants to persist amid temptation to quit. Thus it is remarkable to conceive that performing a seemingly unrelated self-control task with minimal movement should compromise intense exercise performance. Having said that, researchers have successfully demonstrated support for this postulate. For example, Wagstaff (2014) examined the effect of self-regulation prior to 10 km cycling time trial performance. Results showed that when participants were asked to suppress their emotions (hypothesised to require more effort than reappraisal) whilst watching an upsetting video prior to the time trial, they recorded slower times, lower power outputs and rated the exercise more effortful.

Englert and Bertrams (2014) tested the limited strength hypothesis that prior self-control impairs sprint start performance. The authors posited that self-control exertion could lead to a false start or a delayed reaction time. Thirty-seven sport students with previous experience in sprinting were randomly assigned to an experimental or control condition. All participants first performed 3 x 10 m sprints from foot-pressured starting blocks. Next, participants completed a word transcription task in which the experimental group were required to omit the letter *e* and the control group transcribed normally. Thereafter, participants completed a second series of sprints. In keeping with the ego depletion hypothesis, the experimental group recorded slower reaction times, transcribed fewer words and made more mistakes. No false starts were recorded, which is not altogether surprising given that false starts are often the result of increased pressure during competition. As the participants performed the sprints alone then it is unlikely there was any real demand for self-control over false starting. In a similar study, the same research team (Englert, Bertrams, Furley, & Oudejans, 2015) examined the effects of distractibility on performance by instructing participants to shoot 30 basketball free throws whilst listening to an audio recording composed of worrisome thoughts experienced during high-pressure situations. Participants paid more attention to the audio recording and performed worse. Again, the results are encouraging for the strength model.

In the years since Hagger et al’s meta-analysis (2010), there has been a rapid rise in the number of self-control studies replicating the ego depletion effect. More recently, however, the strength model has come under increasing scrutiny. Carter and McCullough (2014) rather boldly questioned the robustness of the depletion effect and effect sizes previously reported. The authors applied methods for estimating and correcting for small-study effects to the data from this previous meta-analysis effort, concluding they found very strong signals of publication bias, along with an indication that the depletion effect is actually no different from zero. The authors concluded that until greater certainty about the size of the depletion effect can be established, circumspection about the existence of this phenomenon is warranted and that, rather than elaborating on the model, research efforts should focus on establishing whether the basic effect exists.

2.3.2 Conserving Self-Control Strength

The initial prediction of the strength model was that a lack of energy supply could explain the ego depletion effect. However, later research suggested that self-control does not just depend on available capacity. Muraven et al. (1998) suggested that if the resource is limited then in all likelihood there exists little of the resource. Thus, self-control ability may also depend on how one judiciously expends resources. For example, if an individual does not want to change behaviour, then poor performance on a task cannot simply be ascribed to a lack of self-control strength. Under this circumstance, performance is likely to depend on the individual’s motivational state. Similarly, if the same individual does want to change but the effort required to maintain or improve performance is perceived as too demanding (i.e., there is likely to be some physiological cost or mental strain incurred), then he/ she may decide to withhold effort in anticipation of performing further tasks. To illustrate this latter point, Baumeister (2012) refers to the tired athlete who conserves energy long in advance of truly exhausting their energy stores. The concept of a tired athlete is of course relative. Some athletes are prepared to exert more effort than others and will increase their effort to operationalize energetic resources so that they can maintain the standards of performance required. Ego depletion effects may therefore indicate conservation of a partly depleted resource, rather than full incapacity because the resource is completely gone.

Muraven and Slessareva (2003) tested the above ideas, drawing on both economic (Tversky & Kahneman, 1981) and resource management perspectives (Hobfoll, 1989) to self-control, by suggesting that people are selective in their self-control efforts. When individuals have already lost resources, they are likely to try and minimise the risk of further loss and will therefore be more motivated to conserve the resources they have in anticipation of further potential losses. The authors showed that ego depletion could be countered if participants are sufficiently motivated. Using a dual-task design, participants were assigned to either a depletion or non-depletion condition in which they were asked to either refrain from laughing whilst watching a comedy video clip, or simply watch the video with no instructions as to how to behave. Following this, participants were then asked to consume either a sour or sweet-tasting beverage. When participants were paid based on their self-control performance (i.e., more money for exerting self-control) they drank more of the sour-tasting beverage compared to those who did not have to exert self-control in the first task. The authors suggest that if participants were truly depleted then they would not have been able to exert further self-control. Moreover, it may well be that people simply mobilise resources for tasks deemed important or to have some benefit (i.e., personal reward).

Muraven, Shmueli, and Burkley (2006) extended the above ideas by manipulating participants' expectations of how much self-control they would have to exert. They reasoned that if people expect to exert self-control in the future, their motivation to conserve should be increased and that this should be especially likely if their ego strength has been already depleted. In the first experiment of four, participants were asked to self-control a well-learned pattern by typing a paragraph without hitting the *e* key. Participants in the control condition just typed the paragraph as they saw it. They were then told that they would take two more tests but half of the participants were led to believe that the final task did not require self-control. The first of these additional tests was the Stroop task. After that, they would have to solve anagrams that were either described as requiring them to “think hard” (low self-control) or “override impulses” (high self-control). Participants who had to exert self-control in the first part of the experiment and who expected to exert self-control in the future exhibited poorer self-control on the Stroop task as compared to those who did not exert self-control in the past or those who did not expect to exert self-control in the future. Further evidence for conservation of self-control strength came from participants’ actual performance on the final task. In particular, how long they persisted on difficult and frustrating anagrams before quitting. There was a negative correlation between Stroop performance and time spent on the anagrams, suggesting a trade-off in resource use; i.e., worse performance on the Stroop (which would suggest conserving) was associated with greater self-control on the anagram.

Although it is possible for individuals to expend more of their self-control strength, conserving any remaining resources for times of need appears to be an adaptive response and might explain ego depletion effects (Beedie & Lane, 2012). Indeed, empirical tests of the conservation hypothesis have involved the addition of further self-control tasks, following the typical dual-task paradigm (Graham, Bray, & Ginis, 2014; Muraven, Shmueli, & Burkley, 2006; Tyler & Burns, 2009). Graham et al. (2014) adopted a sequential task design comprising an initial endurance handgrip squeeze followed by the Stroop task and two additional handgrip squeezes. Participants were allocated to one of four experimental conditions to investigate the after-effects of anticipating future self-control and motivation on self-control depletion patterns. The results showed that participants who received autonomy-supportive instructions produced significantly better results on a third self-control task yet performed worse than controls on the fourth task. The authors concluded that anticipating future demands may result in a short-term detriment to performance but not in the long-term.

2.3.3 Does Self-Control Rely on Glucose?

A substantial literature has developed on the measurement of mental effort, notably blood glucose as a metabolic correlate of energy mobilisation (e.g., Benton, 2002; Fairclough & Houston, 2004). Although Muraven et al. (2003; 2006) provided an alternative account for the effects of prior self-control exertion on further self-control attempts, the notion that a central pool of resources warrants conservation still implies it is limited in supply. In a further set of studies Gailliot et al. (2007) operationalised ego depletion based on fluctuating blood glucose levels. Gailliot et al's (2007) experimental findings showed that self-control lowered glucose levels (Studies 1 and 2); predicted poor performance on a subsequent self-control task (Studies 3-6); and when replenished exogenously, eliminated any performance impairments (Studies 7-9). In one of the studies, participants completed an attentional control task, which involved attending to a visual cue whilst watching a video, before completing a Stroop task. Baseline glucose levels (96.07 $\pm$ 22.08 mg/dL) did not predict Stroop performance, but lower glucose (91.67 $\pm$ 17.77 mg/dL) after watching the video was significantly associated with poorer Stroop performance.

Given what is known about cerebral energy metabolism then it is highly plausible that glucose should be a factor in self-regulatory effort. Chiefly, that blood-borne glucose is the brain’s preferred fuel (Bliss & Sapolsky, 2001; van Hall, Stromstad, Rasmussen, Jans, Zaar, Gam et al., 2009); is used to make neurotransmitters, which play a role in the onset of fatigue (Mergenthaler, Lindauer, Dienel, & Meise, 2013); and is released from the liver into the bloodstream to fuel brain processes in response to stress (Coker & Kjaer, 2005), make the glucose hypothesis a compelling argument. Furthermore, when considering a broader perspective on links between energy and self-control outcomes, there is a wealth of evidence linking type 2 diabetic symptoms (i.e., poor glucose tolerance) with negative emotions (e.g., DeWall, Pond, & Bushman, 2010; Mezuk, Eaton, Albrecht, & Golden, 2008).

However, closer examination of Gailliot et al’s findings suggests that there are significant conceptual and empirical caveats associated with their work. Kurzban (2010) provided a compelling rebuttal of the glucose-based account, questioning the notion that the individual becomes depleted in a literal sense. Kurzban argued that the caloric cost of brain activities such as those involved in the tasks used in Baumeister’s laboratory equate to the same amount of calories contained in a tic-tac. According to Kurzban—from a computational perspective—a resource account considers the drop in the charge of a battery as opposed to considering the remaining charge in that battery.

Kurzban’s (2010) critique also focused on the methodological rigour, specifically the measurement tools used to assess glucose. Accurate measurement is important for theory development and, consequently, problems associated with measurement warrant close scrutiny and rapid resolution. The small changes in blood glucose require a precise and accurate tool and one within minimal error. The Accu-Chek unit has been used extensively to measure blood glucose across self-control tasks (Gailliot et al., 2007; Niven et al., 2013). Evidence suggests that the Accu-Chek consistently fails to meet high standards of test–retest stability (Hoedemaekers, Klein Gunnewiek, Prinsen, Willems, & Van der Hoeven, 2008; Khan, Vasquez, Gray, Wians Jr, & Kroll, 2006). Furthermore, Van Vlasselaers et al. (2008) found that the bias for the Accu-Chek was 6 mg/dL with wide limits of agreement and a variable over- and underestimation of the actual blood glucose value depending on the level of blood glucose (hypo-, normo-, or hyperglycemia). Given these issues, it would appear that these results perhaps reflect a “false positive”.

Rather than just look at the total amount of resources one has available for self-control, then understanding how people exert self-control successfully under conditions of so-called mild depletion could be juxtaposed with physiological responses to exercise at submaximal intensities. Improved submaximal exercise performance is associated with a lower cost of oxygen (i.e., less oxygen is required to perform at a given workload), which is thought to reflect improved muscle efficiency and oxygenation. Recent research suggests efficiency could be the mechanism for good self-control. Niven, Totterdell, Miles, Webb, and Sheeran (2013) showed that good self-regulators are not just *cognitively efficient* but also exert self-control in a *physiologically efficient* manner. The authors found that individuals who self-reported themselves as good emotion regulators were able to achieve a positive mood with less cost to their self-regulatory resources than those participants who reported being poor emotion regulators. Niven et al.’s interpretation of these findings was that good emotion regulators have developed relatively automatic (i.e., efficient) means of regulating their emotions. That is, those who are able to improve their emotions with no additional cost to blood glucose may have learned to use affect-improving strategies that are more efficient (i.e., reappraisal rather than suppression). In contrast poor regulators may not have developed the same efficient mechanisms and therefore have to expend deliberate effort to improve their feelings.

Extending the above, there is considerable evidence from both animal and human studies to suggest that exercise elicits favourable changes to how glucose is produced and utilised. For instance, Goodyear and Kahn (1998) showed that an acute bout of exercise increases total muscle glucose transporter sites. Burgomaster, Heigenhauser, and Gibala (2006) showed that short-term sprint interval training increases muscle glycogen content at rest and after training, as well as a decrease in net muscle glycogenolysis decrease during submaximal exercise. Further evidence that glucose production is not an issue is provided by Matsui, Ishikawa, Ito, Okamoto, Inoue et al. (2012). The authors exercised adult male rats to exhaustion at moderate intensity by treadmill and found that glycogen supercompensation occurs in the brain, just as it does in skeletal muscle. Increases in basal glycogen levels in the cortex and hippocampus, which are involved in motor control and cognitive function, were observed four weeks after testing. Related research findings are offered by Kratz, Lewandrowski, Siegel, Chun, Flood et al. (2002) who assessed a number of basic biochemical parameters in 37 marathon runners before and after competition. They found glucose (mg/dL) was elevated before (47.4-151.4); 4hrs after (63-158); and 24 hours (67-167) following the race. However, this effect does not appear to be immediate, as Kraemer and Brown (1986) reported a significant decrease in glucose 5 minutes after a marathon run compared to levels sampled within 1 hour 52 minutes before the run.

Another way to look at the role of glucose in self-control is to consider evidence that suggests the brain may not always prefer to use glucose and that physiological mechanisms have evolved to respond to stressors. For example, researchers have demonstrated that the brain is also capable of oxidising several other substrates including acetate, glutamate, ketone bodies (Sokoloff, 1973), and lactate (Dieniel, 2012). In particular, lactate may indeed be preferred to glucose during neuronal metabolism. If, under stress, lactate is oxidised and thereby spares glucose (Quistorff, Secher, & Lieshout, 2008; Van Hall et al., 2009), it would appear that the human brain is more than capable of maintaining its own energy supply. This adaptation is also apparent under hypoxic conditions as the increase in lactate and adenosine increases lactate metabolism and decreases glucose utilization (Bliss & Sapolsky, 2001). Schurr et al. (1997) concluded that lactate can be utilised by the brain for energy metabolism during recovery from hypoxia; is preferable over glucose in states of hypoxia; and is used for the re-oxygenation for recovery of synaptic function, when ATP levels are depleted.

Despite the fact that several mechanisms are known to stimulate glucose production and limit glucose utilization, a deeper understanding of what mediating factors initiate energy production for self-control is needed. Carter and colleagues (Carter, Jeukendrup, & Jones, 2004; Carter, Jeukendrup, Mann, & Jones, 2004) argued that ingesting a carbohydrate solution during high-intensity exercise may act as a signal to increase the neural drive associated with motivation, which explains why participants were able to improve their performance. In a similar study, Chambers, Bridge, and Jones (2004) showed that a simple mouth rinse of a carbohydrate solution improved one-hour cycling time trial performance, compared with water. The authors posited that the drink may act on taste receptors that activate brain regions involved in reward and the mediation of emotional and behavioural responses. Similar studies have demonstrated that glucose may act as a cognition enhancer through the allocation of attentional resources, thereby linking human decision making to metabolic cues (Scholey, Sünram-Lea, Greer, Elliott, & Kennedy, 2009; Wang & Dvorak, 2010). Yet according to Burke, Hawley, Wong, and Jeukendrup (2011) the specific mechanisms through which peripheral changes in glycogen availability are signalled to the brain, and the fate of the increased carbohydrate uptake, remain unclear. Investigating the neurophysiological mechanisms underlying self-control processes following carbohydrate ingestion would be a logical extension of theoretical work in this area.

Collectively, the literature suggests that glucose could be an important moderator of self-control performance buts its supply is not simply compromised by engaging in effortful tasks. Rather, there are likely to be several biological and environmental factors that interplay to explain self-control outcomes. To conclude this section, then, integrating the findings for glucose depletion and supplementation with physiological indicators of self-regulatory effort will provide an important account of the processes and mechanisms behind the ego depletion effect. To date, no study has adopted measures of blood glucose and glucose supplementation alongside analogues of physiological effort to investigate the ego depletion effect.

2.3.4 Recovery of Self-Control Resource

Muraven and Baumeister (2000) argued that full self-control capacity can only be restored if there is a sufficient recovery period following depletion. Consequently, Researchers have tested the effect of rest or relaxation between self-control tasks (Oaten, Williams, Jones, & Zadro, 2008; Tyler & Burns, 2008). Tyler and Burns (2008) used two experiments to demonstrate: 1) the effect of different durations between two self-control tasks; and 2) the effect of a 3-minute relaxation period between tasks. Experiment 1 showed that performance is almost maintained after a 10-minute break, with partial restoration achieved after 3 minutes, and little benefit for a 1-minute interlude. In Experiment 2, a relaxation period, which involved doing nothing, was an effective intervention. For more prolonged initial depleting tasks, Oaten et al. (2008) found that a 45-minute break only resulted in partial recovery. Together, these results indicate a *dose-response* effect for recovery with shorter recovery only resulting in partial replenishment and a period of rest proportional to the duration of the depleting task necessary for full recovery.

The duration of the recovery spell relative to the self-control demands of the depleting task is a consideration and would support existing theory in exercise physiology. Fatigue progresses during exercise and starts to recover upon cessation of exercise (Taylor & Gandevia, 2008). In an exercise context, it is important to take into account the duration and intensity of the exercise when considering the amount of time required to restore fully self-control resources. Offering no interim period would provide less opportunity for participants to recover their self-control resources thereby leading to a larger ego depletion effect. Fully replenished self-control resources will maximise the probability that the exerciser will be able to exert self-control to engage in the next exercise session. Quantifying the recovery needed relative to the task could be potentially challenging. Before that is achieved, research needs to be able to accurately describe what makes a self-control task mildly depleting as opposed to severely depleting.

2.3.5 Restoring Self-Control Strength

One of the fundamental assumptions of the limited resource account was the idea that the exertion of self-control should consume resources more quickly than they can be replaced, thereby resulting in a net decrease in available resources. If people are unable to replenish their strength because circumstances prevent them from resting, then they may become chronically deficient in resources and hence impaired at self-control. How then does one counter the ego depleted state in the short-term?

In their updated strength model, Baumeister et al. (2007) proposed "… consistent with the conservation hypothesis, people can exert self-control despite ego depletion if the stakes are high enough" (p. 352). Several researchers have demonstrated how individuals might circumvent regulatory depletion effects and maintain or improve subsequent performance, using motivational incentives (Alberts, Martijn, Greb, Merckelbach, & de Vries, 2007), emotion manipulations (Beedie et al., 2012; Tice et al., 2007), and implementation intentions (Duckworth, Grant, Loew, Oettingen, & Gollwitzer, 2011; Koningsbruggen, Stroebe, Papies, & Aarts, 2011).

Alberts et al. (2007) showed how motivation can be activated via non-conscious processes (i.e., automatic activation of goal-directed behaviour). They found that depleted individuals who were given primes related to persistence (either by unscrambling sentences with persistence words in them or seeing a screensaver with motivational images) performed better than depleted individuals not given these primes.

Ren, Hu, Zhang, and Huang (2010) conducted two studies that provide evidence that emotions play a role in self-control processes. The authors investigated the effects of implicit stimuli (i.e., viewing images of smiling faces) to enhance positive emotional states, as a method to counteract ego depletion. Over two experiments the participants who were depleted and then exposed to positive subliminal stimuli persisted for longer on a subsequent self-control task than the participants who were exposed to neutral subliminal stimuli. Ren et al. concluded that inducing positive emotion through implicit stimuli is an effective method for restoring self-control strength following depletion. Similar to Ren et al. (2010), Blanchfield, Hardy, and Marcora (2014) found subliminal affective priming (Experiment 1: visual cues depicting happy and sad facial expressions; Experiment 2: action and inaction words) altered perceived effort with participants cycling for longer on a time-to-exhaustion test when subliminally primed with happy faces.

Bray, Oliver, Graham, and Martin Ginis (2013) sought to mitigate the effects of self-control depletion by exposing participants to a positive emotion manipulation, via listening to self-selected uplifting music. Building on the strength model the authors predicted that participants who listened to a selection of uplifting music would report more positive emotional responses than depleted participants who rested quietly without music. Furthermore, it was predicted that, after being exposed to a self-control depletion task, participants who listened to a selection of emotionally uplifting music would perform better on an exercise endurance task than participants in a quiet rest (no music) control condition and similar to participants in a no-depletion control condition. Findings showed that although uplifting music elicited positive emotions, the response did not replenish self-control strength, as measured by performance on a second handgrip squeezing endurance exercise.

Adrianaase et al. (2010) suggest one method to overcome the barriers to goal achievement (such as engaging in counterproductive behaviour) involves combining mental contrasting with implementation intentions (if-then planning). Mental contrasting is a self-regulatory thought process whereby one imagines the attainment of a desired future outcome (e.g., losing weight, exercising more frequently) and then contrasts it with existing reality (e.g., current dietary habits, lifestyle, exercise regimes, etc.). The process works by firstly identifying the goal (e.g., "to go for a run 4 days per week") and then describing in depth the most positive aspect of attaining this goal; and thinking about the best thing that would happen if one went for a run four times per week. Following this, one then identifies the biggest obstacle to reaching the goal. Once this has been done the mental contrasting exercise follows the same process for the "next best" outcome of goal achievement followed by identifying the "next biggest obstacle" that impeded their route.

Forming simple plans known as implementation intentions (if-then plans; Gollwitzer, 1999), involves specifying when, where, and how one will act. The idea is that by forming a readily available cue to act on a critical situation, people can strive towards their goals. Thus, when the critical situation arises, the new plan of action should counteract the habitual response. Implementation intentions take the form of "When situation X arises, I will perform Y!" The person simply commits himself or herself to responding to a situation in a certain manner. An example could be: "If I don't feel like exercising today …then I will say to myself: 'If I train today, I am more likely to achieve my goal!'" By forming these simple if-then plans, individuals are able to shield goal-directed behaviour from distraction, remember proactive behaviour, and conserve self-control strength (Henderson, Gollwitzer, & Oettingen, 2007). The person will be more likely to initiate goal-directed behaviour when they encounter a situation likely to threaten goal attainment if they have a readily accessible and highly automated plan that does not require conscious deliberation.

2.3.6 Self-Control Training

Although exerting self-control is proposed to impair performance, at least in the short-term, the long-term effects could be quite the opposite. Returning to the muscle analogy, just as a muscle grows stronger with exercise, then regular exertion (i.e., training) of one's self-control appears to result in improved self-control performance (Muraven & Baumeister, 2000). Furthermore, the proposal that the resource for self-control is used across domains suggests that, for athletes, practicing self-control in one domain (i.e., inhibitory control) could benefit self-control in a performance domain (i.e., greater task persistence). Although it is perhaps this aspect of the strength model that is so appealing, the self-control training hypothesis has received considerably less attention.

In their meta-analysis, Hagger et al. (2010) reported a *large* effect size (d = 1.07) for self-control training. However, for individual studies the reported effect sizes vary considerably from *medium* (d = 0.48; Hui et al., 2009) to *extremely large* (d = 8.59; Oaten & Cheng, 2006a). These convergent findings warrant consideration before concluding that self-control training is beneficial for performance. For example, what are the mechanisms explaining the training effect? To what extent does training aid, or even compromise, performance? The application of self-control training to sport has important implications. The proposal that self-control training transfers across different task domains goes against the principle of specificity that governs the prescription of sports training. For athletes who are well trained, are short-term improvements in self-control ability likely to transfer to meaningful performance changes?

The typical approach for self-control training studies is to ask one group to practice self-control tasks as opposed to a control group who do no training, and then assess both groups on a dependent self-control task. For instance, Muraven, Baumeister, and Tice (1999) tested the training hypothesis in a longitudinal study: first assessing for an increase in baseline self-control (akin to a muscle increasing its power in a single all-out effort) and second, its stamina (as measured by first and second efforts). This was tested using the handgrip squeeze exercise, a thought-suppression task, and a second handgrip squeeze. The authors instructed participants to complete a series of self-regulatory exercises over two weeks, such as posture regulation, keeping a food diary, or improving mood. Follow-up assessment showed that experimental group participants squeezed the handgrip dynamometer for longer than the control, thus suggesting that training builds resistance to resource depletion. However, there was no improvement in the absolute scores for the handgrip squeeze and the control group actually performed worse in the second session. Results did however show the largest improvements in performance for those who closely followed the instructions (as evidenced from daily diaries).

Hui et al. (2009) got participants to engage in either a strong training programme (work on the Stroop task for five minutes twice a day for two weeks and rinse with a mouthwash that produces a powerful burning sensation) or a weak training programme (no conflict between ink colour and word; diluted mouthwash). At the end of this training, participants returned to the laboratory and engaged in several tasks that required self-control. As compared to those who had no training or those who had the weak training, the strong training group performed better on the post training self-control tasks. They held their hand in ice water significantly longer; performed better on a visual search task that required regulating attention and concentration; had better dental care (based on amount of dental floss and toothpaste used), and reported better health-related behaviours.

Regular engagement in tasks that demand self-control such as using the non-dominant hand to perform everyday tasks, modifying speech (e.g., avoiding use of colloquialisms), controlling emotions, modifying posture, monitoring diet, and regular use of an aversive mouthwash has been shown to lead to increased exercise adherence (Gailliot, Plant, Butz, & Baumeister, 2007; Muraven, Baumeister, & Tice, 1999). Field research has also demonstrated that long-term practice on self-control tasks such as engaging in a regular programme of academic study also results in significant increases in exercise participation (Oaten & Cheng, 2006a).

Muraven (2010) assigned smokers who were interested in quitting to one of four tasks to practice for two weeks before beginning a cessation attempt. Two of these conditions required self-control (avoid eating sweets and squeeze a handgrip exercise for as long as possible twice a day) and two did not (maintain a diary of any time they exert self-control and work on difficult math problems). Consistent with previous research, smokers who practiced tasks that required self-control remained abstinent longer than smokers who practiced tasks that did not require self-control. Moreover, the control tasks evoked awareness of self-control, increased self-monitoring and increased self-efficacy, and participants expected these tasks to be helpful in their cessation attempt.

Before this type of training should be suggested to athletes, there are several limitations that warrant consideration before generalising the findings. One aspect of this is specificity and thus encouraging self-control training in different domains would go against a wealth of evidence that suggests practice is more beneficial when it closely resembles the actual performance that is being simulated. Braver, Paxton, Locke and Barch (2009) found inhibitory control to improve on specific self-control tasks, thus supporting the principle of specificity.

2.3.7 Individual Differences in Self-Control

Baumeister et al's (2007) strength model offers a largely situation-dependent account of self-control (i.e., resource availability determines self-control). However, several researchers, including Baumeister and colleagues, while trying to explain the sometimes mixed findings originating from studies examining the effects of influence strategies, have focused on possible individual differences in behavioural responses to self-control tasks. Working from this perspective, self-control has been shown predict behavioural outcomes in contexts such as health (Imhoff, Schmidt, & Gerstenberg, 2014; Schroder, Ollis, & Davies, 2013), education (Tangney, Baumeister, & Boone, 2004), and crime (Moffitt et al., 2011). De Ridder, Lensvelt-Mulders, Finkenauer, Stok, and Baumeister (2011) meta-analysed findings from 102 studies assessing behavioural effects of self-control using trait self-control measures. Associations between self-control and behaviour were strongest for behaviours that were automatic, such as breaking and forming habits, and imagined (e.g., behaviour one intends to do, thinks one can do, or thinks one should do). Furthermore, individual differences in self-control have been shown to interact with resource depletion, as measured by performance on behavioural self-control tasks used in dual-task paradigm experiments (Schmeichel & Zell, 2007).

Individuals with high trait self-control (TSC) appear to achieve greater success in later life (e.g., Mischel, Shoda, & Peake, 1988). Moffitt et al. (2011) showed that childhood self-control (assessed from the ages of 3-11 years old) predicted physical health, wealth and crime outcomes later in life (at the age of 32 years old). The authors used staff observations during a 90-minute data collection session to assess self-control behaviour (such as low frustration tolerance, impulsivity and lacking persistence) during childhood; each characteristic was assessed using a Likert scale (0 = *not all*; 1= *somewhat*; 2 = *definitely*). In addition, the authors also followed a cohort of 500 British-twins, reporting that the sibling with the lower self-control score had poorer outcomes. More recently, Berman et al. (2013) examined individual differences in self-control: first, at the age of 4 years old and then, subsequently, 40 years later. The authors assessed participants' ability to delay gratification using a working memory task while tracking brain neural responses and found that low delayers (low self-control) recruited higher-dimensional neural networks. In other words, those who were classified as poor at self-control were also less efficient at recruiting cortical networks to achieve the same behavioural performance. The ability to predict performance, with 71% accuracy, suggests that brain activation patterns could be a useful measure to predict self-control abilities.

Imhoff et al. (2014) provided empirical support for the notion that individuals with high trait self-control seem to avoid dangerous temptations, rather than actively inhibit impulsive responses. Ent, Baumeister, and Tice (2015) produced similar findings, reporting that high TSC was positively correlated with avoiding temptation; people high (vs. low) in TSC were more likely to avoid distraction; and people high in TSC avoid, rather than merely resist, goal-inhibiting impulses. The authors concluded that people with high TSC reported weaker desires overall, suggesting that they are more successful than their low TSC counterparts at avoiding strong desires. Further, those high in TSC reported lower rates of resistance, suggesting that they did not have to use self-control as often as those low in TSC. By avoiding tempting situations, motivational conflicts, and problematic desires, people with good self-control apparently manage to avoid having to resist strong desires that conflict with their goals and values. Their avoidance of problematic desires and overall relative weakness of desire were perhaps offset by lower rates of conflict and resistance, so that they ended up acting out the desires they did have at roughly the same rate as people with low self-control.

While there is some evidence to suggest an interactive effect, meta-analytic findings by Hagger et al. (2010) suggest the moderating influence of TSC has produced mixed results. For example, some studies have found an interaction between self-control depletion and TSC (e.g., Dvorak & Simons, 2009; Study 2; Gailliot & Baumeister, 2007), while other studies have produced no such findings (e.g., Study 1; Gailliot & Baumeister, 2007; Stillman, Tice, Fincham, & Lambert, 2009).

It is plausible that poor psychometric integrity may in part account for equivocality regarding the moderating influence of TSC on self-regulatory performance. Thus, assessment of a valid and reliable measure of trait self-control (TSC) could be considered a worthwhile endeavour for researchers and practitioners through the ability to identify those individuals who might be susceptible to poor self-control, as well as drawing attention to actions and behaviours that require self-control.

Tangney et al. (2004) developed The Self-Control Scale (SCS) and Brief Self-Control Scale (BSCS) to complement their conceptualisation of self-control. The scales assess self-control across four major behavioural spheres (controlling thoughts, emotions, impulses, and performance), and were used by the authors to predict outcomes such as academic achievement (i.e., better grade point average) and psychological adjustment (that is, the ability to maintain a balance of positive feelings towards one's life and self in the process of dealing with stress). They claimed they had established good test-retest reliability by reporting coefficient alphas of .89 for the SCS and .87 for the BSCS.

Self-report represents a useful and practical method for athletes and practitioners who want to identify key self-control behaviours that are vulnerable to lapses in self-control. Moreover, self-reports of self-control can be used to inform intervention design and evaluation. Given the abstract nature of psychological constructs, and the possibility that they may be influenced under different situational contexts, researchers are encouraged to demonstrate stability if they are to emphasise that dispositional trait measures are valid (Lane, Nevill, Bowes, & Fox, 2005; Nevill, Lane, & Duncan, 2015; Nevill, Lane, Kilgour, Bowes, & Whyte, 2001). Nevill et al. (2001) pointed out that self-reporting relies on perception, and as these are at best estimates, then some variation is possible. To overcome this problem, the authors suggest researchers conduct an item-by-item analysis rather than using a summary statistic (i.e., alpha), and recommend that the majority of participants (90%) should record differences within a $\pm$1 referent value for 5-item scales. As Tangney et al. (2004) used factor scores it is not possible to determine if one item has a greater degree of stability than others.

In an unpublished study, Fullerton, Lane, Nevill, and Devonport (2016) examined the test-retest stability of the BSCS among a sample of endurance athletes over two-week period, using the methods proposed by Nevill et al., (2001). The authors found that 8 of the 13 items appear to reflect relatively stable self-control behaviours (i.e. >90% of participants reported test-retest differences within $\pm$1). They found that items tapping into the ability to self-regulate behaviour towards goals and standards, namely the ability to maintain self-discipline (Q6: “I refuse things that are bad for me”) and work towards long-term goals (Q11: “I am able to work effectively toward long-term goals”) appear to be stable, suggesting these characteristics are more trait-like among athletes. The findings are not altogether surprising that athletes are stable in these spheres as the inherent nature of sport fosters goal-setting, adherence and striving over a prolonged period of time.

However, Fullerton et al. (2016) argue that, in the context of their findings, the five items that showed poor stability should not be included in a trait measure of self-control. The authors suggest that future research needs to; 1) investigate the reasons as to why athletes report large variations in their perceived self-control ability, and 2) control for situational factors. For researchers examining self-control behaviours among endurance athletes, they should pay particular attention to changes in health-status, training and competition schedules. Research has shown that, under such conditions, athletes experience considerable changes in emotions (Jones, Lane, Bray, Uphill, & Catlin, 2005), which are proposed to influence behaviour (Baumeister, Vohs, DeWall, & Zhang, 2007).

Possessing high self-control presents an interesting paradox. On the one hand, high self-control is beneficial if one has to steer behaviour towards a goal. On the other hand, the failure to manage one’s high capacity for self-control is potentially problematic if one has a tendency to over-control. To give an example, athletes who compete in weight-making dependent sport (e.g., boxing, judo, horse racing) require self-control to follow dietary and training regimes. However, they are reported to frequently over-control aspects of their behaviour, such as regulating eating habits to the extent that energy expenditure chronically exceeds energy intake, and thus they risk severely compromising performance (Wilson, Drust, Moreton, & Close, 2014). Imhoff et al. (2014) provides a different interpretation, suggesting that, rather ironically, individuals who describe themselves as high in trait self-control report greater situational depletion. The authors surmised that these individuals avoid tempting situations, and this means that they rarely engage in active inhibition. As such, they potentially have a weaker ability to resist temptation once they are forcibly confronted with it. Thus, future researchers should investigate under which conditions trait self-control has protective versus detrimental effects on self-control. In particular, researchers are encouraged to consider how situational and task demands might affect a respondent's appraisal of his/her self-control abilities.

2.4 Alternative Models

2.4.1 The Resource Allocation Model of Self-Control

Rather than wholly contest the idea that glucose levels are linked with self-control, Beedie and Lane (2012) provided an alternative way to think about the role of glucose in self-control processes by considering: 1) the evolution of mental processes; 2) adaptation; and 3) the physiology of glucose transport. In their resource allocation model of self-control (RAMS), Beedie and Lane suggest that glucose it likely to act as a physiological mediator of the motivational and behavioural processes involved in self-control. They propose that the expenditure of energetic resources is governed by an appraisal of the situation in the context of available resources and immediate individual priorities. This is based on the idea that if the self-control task has implications for personal priorities, the individual will allocate resources towards maintaining self-control.

From an evolutionary analysis perspective, Beedie and Lane (2012) argue that the body's regulatory systems are remarkably efficient when it comes to using energy. They reasoned that one or more of the organs or systems involved in self-control would adapt following repeated stress to ensure more effective and economic self-control in future situations. For example, changes in blood glucose concentration are detected in the pancreas. If glucose level falls too low, then the pancreas secretes glucagon, while if glucose level rises too high, the pancreas secretes insulin. This homeostatic mechanism represents a system that maintains a set of essential variables which are the targets of regulation, a target range for each essential variable that defines the boundaries of homeostasis, and a set of regulatory responses which are initiated under stress. However, if the reason for a lack of glucose in the brain areas responsible for self-control is that there has been no priority-driven redirection of resources then low glucose per se is not the cause of a failed attempt at self-control. That is, insufficient glucose availability is the result of insufficient blood flow, itself the result of the self-control task not being sufficiently consistent with personal priorities to cause physiological reprioritization (Beedie & Lane, 2012).

A key component of the model put forward by Beedie and Lane (2012) is the role of motivation and emotion. They argued that these psychological processes have evolved to operationalise physiological resources. Emotions are relatively brief and intense reactions to goal-relevant changes in the environment that consist of many subcomponents: cognitive appraisal, subjective feeling, physiological arousal, expression, action tendency, and regulation (Scherer, 2000, p. 138). Specifically, emotions serve to produce a series of coordinated responses to meet the adaptive challenges of a given situation (Nesse, 2009). According to the evolutionary approach, the key to understanding emotions is to study what functions emotions serve (Izard, 1993). In that way understanding the utility of emotion may be important for understanding a pattern of behaviour.

The same authors had previously tested some of the above ideas by examining the role of emotion regulation during laboratory-based cycling, an activity which requires goal pursuit. Beedie, Lane, and Wilson (2012) manipulated performance feedback, as a method to elicit emotional responses, presented to experienced and competitive cyclists. Participants performed two time trials under two conditions. In the false positive feedback condition, participants were told they were 5% ahead of elapsed time, and in the false negative feedback condition, 5% behind elapsed time. The respective conditions were designed to increase the intensity of pleasant emotions (e.g., excitement) and unpleasant emotions (e.g., anger and anxiety) felt during cycling. The authors found that false negative feedback associated with an increase in the intensity of unpleasant emotions felt (as expected), but also corresponded with an increase in lactate production, heart rate and ventilation in comparison to positive feedback. There was no significant difference in overall time between the conditions, despite the difference in psychophysiological responses. Instead, what the results do show is that where tasks are inherently valued, participants will mobilise effort via the expenditure of energy resources. This discrepancy-reducing behaviour, achieved by either releasing more energy to maintain/increase performance levels or reducing the intensity of performance to ensure completion, is initiated when a personal standard is juxtaposed against the knowledge of one’s current performance. Such behaviour is not activated automatically but is subject to moderating influences such as motivation.

In contrast, negative feedback resulted in participants trying to down-regulate unpleasant emotions at the expense of effort expenditure. Thus, assuming individuals are sufficiently motivated (i.e., remain interested in the task/ willing to increase effort) to maintain or increase power output then performance deterioration is not inevitable. Mauger, Jones, and Williams (2009) had previously shown that the higher proportion of positive feedback responses, given in a trial where correct split time feedback was provided in comparison to a false feedback trial, elicited motivational benefits that allowed a faster time to completion.

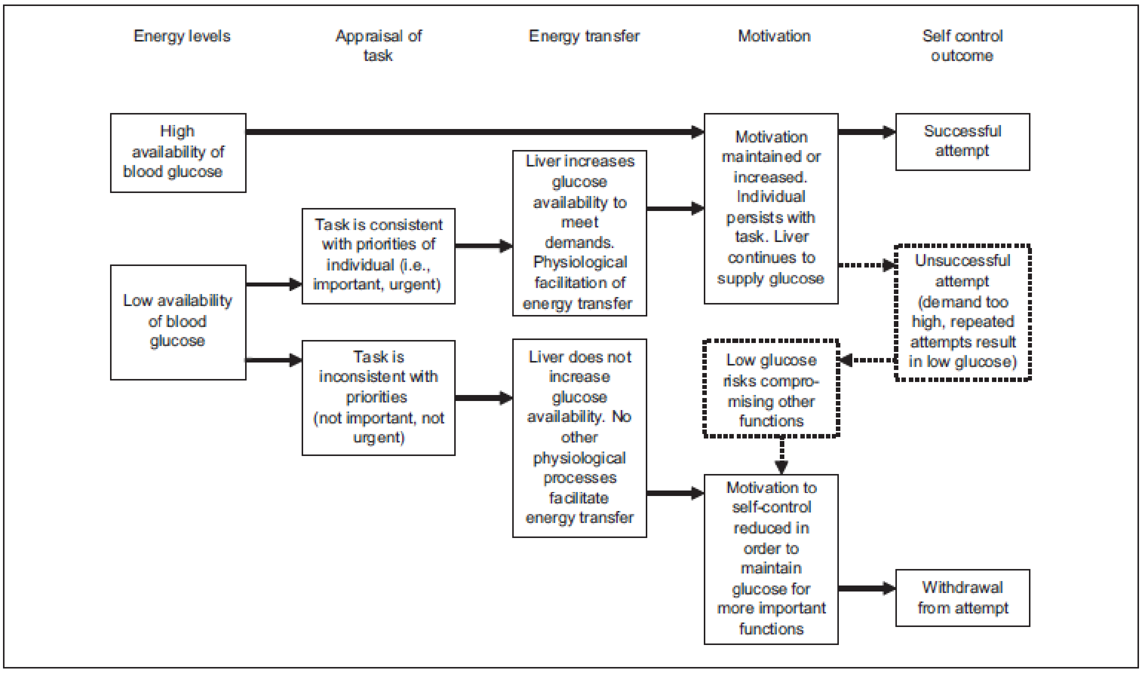


Figure 2. A resource allocation model of self-control. Reprinted from “The Role of Glucose in Self-Control: Another Look at the Evidence and an Alternative Conceptualization” by C. J. Beedie and A. M. Lane, Personality and Social Psychology Review, 6(2), p. 7. Copyright Sage.

As Beedie and Lane (2012) point out, if self-control processes are dependent on motivation, then researchers ought to consider how context determines self-control. They argue that it is not unreasonable to propose that contextual information provided in previous ego depletion studies might bias the processes responsible for task performance. For example, ego depletion studies typically employ manipulations that serve to bias people to conform to instructions. The problem with this procedure is evident in Baumeister, Bratslavsky, Muraven, and Tice’s (1998) laboratory study. The authors presented both cookies and radishes to students, asking half of the group to eat only the radishes, and thus refrain from eating cookies. Participants were then asked to complete an unsolvable puzzle, and volitional control was measured by time spent trying to solve the puzzle. Those who ate radishes, and presumably resisted eating the cookies, persevered for less time on the problem-solving task (8.35 minutes vs. 18.90 minutes). To tease apart whether participants were self-controlling, one must understand the meaning of the task in the context of its meaning with other tasks. The task of resisting eating cookies might hold more meaning for individuals on a diet than for those not on a diet, or for those who require no willpower to not eat cookies. Given that no measure of intention to eat cookies was assessed, the assumption that people will gravitate to eating cookies only becomes justified by the experimental results.

Finally, it is reasonable to suggest that the majority of tasks used in self-control studies are well within the performance capabilities of the individual. Many problem-solving tasks are unlikely to require large amounts of resources. Schmeichel and Vohs (2009) suggested it is possible that trying and failing at a self-control task that is of high personal importance may be perceived as threatening to the individual and thus also depleting. The authors too are critical of the selection of initial self-control tasks (such as suppressing thoughts about a white bear or performing the Stroop Colour-Word Test) that are unlikely to be highly important to participants and therefore unlikely to pose a significant threat to self-worth. However, Beedie and Lane do reason that it is of course possible that, as suggested by Kurzban (2010), the levels of glucose involved in self-control are so small as to be irrelevant in research or application.

2.4.2 Implicit Theories about Self-Control

An interesting perspective is offered by Job, Dweck, and Walton (2010) who suggest that the ability to exert self-control may in fact be no more than a person's belief that self-control capacity is limited. Job et al. reported that glucose ingestion following a self-control task did improve self-control and cognitive performance (via Stroop task performance), but only when people believed willpower to be a limited resource. Conversely, when people believed willpower was not limited, glucose was not needed to sustain high levels of self-control. A second experiment by Miller et al. (2012) demonstrates a similarly strong influence of beliefs about willpower on performance

Martijn et al. (2002) showed that people distinguish between two classes of beliefs about exercising self-control (Experiment 2). The first class of beliefs characterises self-control as energy and comes close to the limited energy model of Baumeister and colleagues. In-line with this explanation, people expect and believe that they have only a limited amount of energy available for their self-control operations and that they are likely to fail when demands are too high. The second operationalises self-control as a matter of motivation (i.e., if you really want to do well, you can). Mukhopadhyay and Johar (2005) showed that participants who think that self-control is an unlimited and malleable ability tend to set more goals. A similar impact of beliefs on self-control was demonstrated in three different studies by Tice, Bratslavsky, and Baumeister (2001). It was shown that when participants believe their moods are susceptible to change, they respond to bad moods by increasing several impulsive behaviours such as eating, procrastination and immediate gratification. However, when people are led to believe that their moods cannot be repaired by enacting impulsive behaviours, all these effects are eliminated. The issue is also reminiscent of the concept of self-efficacy (Bandura, 1986) in the sense that people who believe that self-control is a matter of motivation may be expected to experience more control in a self-control demanding situation than people who believe that their capacity to control themselves depends on their energy level.

Tamir (2009) reported that individuals will tolerate or even increase unpleasant emotions if they believe they will support goal pursuit. Examining this theory with athletes, Lane, Beedie, Devonport and Stanley (2011) explored this logic among runners before competition. Of the three hundred and sixty runners who took part, 15% reported using strategies aimed at increasing anger and/ or anxiety whereas the remaining 85% reported using strategies aimed at reducing the same emotions. The authors suggested that if emotions associated with increased activation, such as anxiety and anger, are perceived as helpful (i.e., instrumental) in achieving success in competition, then an anxious or angry athlete might report feeling happy that he or she is in an optimal psychological state. It is therefore important for individuals to consider the utility of the emotion being experienced in relation to one's beliefs surrounding the emotion and its association with goal attainment.

Clarkson et al. (2010) found that people's perceived levels of depletion predicted their performance on tasks that required self-control. Both depletion and non-depletion [conditions] individuals were given (false) feedback about this depleting task that led them to attribute their resources to external or internal sources. For instance, participants crossed off the letter *e* that is next to, or one away from, another vowel (those in the control condition simply crossed off all *e*s). In addition, participants were told that the colour of the paper could either: “exhaust and deplete their ability to attend to information” or “energise and replenish one’s ability to attend to information” (p. 33). In the low depletion condition, the replenishment feedback led to greater persistence on a subsequent task than the depletion feedback. This pattern was reversed in the high depletion condition. In short, people’s perception of their level of self-control resource was a predictor of their subsequent self-control performance regardless of their actual level of resource.

Of particular relevance to the above ideas is the placebo effect, a well-known phenomenon in sport. Researchers have examined the idea that beliefs about certain products or interventions enhancing performance might actually improve performance (see Beedie & Foad, 2009, for a review). In a study in which cyclists’ time-to-exhaustion increased when shown a clock that had been manipulated to run slow, a faster running clock did not produce a significant change in time-to-exhaustion (Morton, 2009). Any deviation of actual rating of perceived effort (RPE) from the expected RPE trajectory is thought to act as a cue to modify pacing (Parry, Chinnasamy, Papadopoulou, Noakes, & Micklewright, 2011; Swart et al., 2009; Tucker & Noakes, 2009). According to Morton (2009), the perceived longer duration signals a threat to task completion because the maximum tolerable RPE would occur before the end of the task. Consequently, it is proposed that participants have to cycle faster to complete the task sooner or modify their RPE template. In summary, the above discussed studies raise the possibility that implicit theories or expectations moderate the ego depletion effect.

2.5 General Discussion

Anecdotally most people would agree that achieving self-control requires effort and motivation. However, reaching agreement on the underlying mechanisms has not been achieved. Over the past decade, much of the research focus has stemmed from the empirical findings of Baumeister and colleagues. This review highlights some obvious synergies between the self-control and sports performance literatures. It also suggests the strength model, in its current form, does not provide a sufficiently robust mechanistic explanation for the observed behaviour on self-control tasks. There appears to be consensus that self-control is not dependent on glucose, thus downplaying the likelihood that a limited resource explains self-control failure. However, to entirely dismiss the role of glucose, and indeed that of a resource-based account, without further empirical work would be premature. When seen collectively and ignoring the glucose hypothesis, then most rebuttals actually corroborate the aptness of the muscle metaphor for explaining self-control, rather than reject it. In terms of developing this conceptualisation, then, the review has considered a range of alternative perspectives that may provide useful directives for future researchers (Beedie & Lane, 2012; Inzlicht, Legault, & Teper, 2014; Inzlicht, Schmeichel, & Macrae, 2014; Muraven, Shmueli, & Burkley, 2006).

To highlight a major limitation of the self-control proposals stemming from Baumeister et al.'s work, the challenge for researchers is to select meaningful tasks in experimental research designs that serve to maximise the relevance of laboratory-based effects to the real world. As Beedie and Lane (2012) suggested, whatever the task or population chosen for a study, identifying the priorities of participants, or recruiting participants to whom the task is meaningful, should form part of the research process. Even so, the degree to which any selected task is meaningful to any one individual will vary substantially, even within apparently homogeneous groups.

The problem is perhaps best illustrated by returning to the muscle analogy. Despite most athletes being able to summon a final end spurt or one last-ditch-effort to achieve success, when there is a motivational urge to do so, there comes a point when muscular activity can no longer be sustained and fatigue sets in. Just as there is lively debate regarding whether fatigue is a centrally, rather than peripherally, driven process, the mechanisms underlying self-control strength are likely to be elucidated using a broader theoretical perspective.

2.5.1 Concluding Remarks

Despite the impressive replications of the ego depletion effect across diverse domains, including sport and exercise psychology, the strength model has come under increasing scrutiny in recent years (Carter & McCullough, 2014; Kurzban, 2010; Lange, Seer, Rapior, Rose, & Eggert, 2014; Schimmack, 2012). Thus in the first instance, more research is needed to examine whether the ego depletion effect exists. For researchers, the potential inherent in this approach should help bring to light the functional significance of self-control and the mechanisms that evolved to support it. Researchers should then be able to develop novel and interesting experimental protocols, beyond asking participants to perform tedious computer-based tasks, or provide extensive self-report data. The context of sport offers huge promise in this area. Many of the interventions employed to improve sports performance could offer insight into how self-control is improved and help shift the emphasis from performance failure to performance success. All too often research is conducted in silos, yet herein lies a problem that draws on extensive research into humans as social organisms and recognises the role of biology in human behaviour. By unifying theories of the self and physiological fatigue, researchers can hope to achieve a more thorough understanding of self-regulatory fatigue (Englert & Bertrams, 2015; Evans, Boggero, & Segerstom, 2015; Marcora, Stainio, & Manning, 2009).

Chapter 3: Task Familiarisation Cancels the Resource Depletion Effect: A Test of the Strength Model of Self-Control in Cycling

3.1 Abstract

Research has found that when individuals exert self-control on repeated tasks, they perform worse on subsequent tasks than individuals who did not need to exert self-control. Worse performance on the second self-control task is interpreted as evidence that the first self-control task is fatiguing. Thus, to demonstrate self-control failure the first self-control task must be sufficiently demanding. The purpose of this first study was to investigate the efficacy of the first test of self-control, using a commonly used approach to assess self-control. Two experiments were completed: In Experiment 1, forty-eight participants randomly performed a cognitive task requiring self-control (incongruent Stroop) or no self-control (congruent Stroop), followed by a virtual reality cycling task and additional iteration of the Stroop task, in a sequential-task design. Results demonstrated no significant difference in cycling performance for the two conditions. However, the experimental group performed worse across the two Stroop tasks. In Experiment 2, forty-three participants followed the same protocol used in Experiment 1, with an additional iteration of both tasks (Cycle-Stroop). Experimental and control groups both recorded faster cycle (9% vs. 8%) and Stroop task times (13% vs. 9%) in these additional tasks with no significant between-group differences. Findings support the proposal that motivational and behavioural processes are often initiated when participants are provided with multiple attempts to detect and correct discrepancies between current and desired states. Future research should investigate factors that influence self-control using methodologies that combine both ecological and internal validity.

3.2 Introduction

Self-control (or self-regulation) is the deliberate effort to alter the way one feels, thinks, acts or performs: for example, persevering despite a discouraging failure (Baumeister, 2012). It follows that possessing high levels of self-control should be beneficial for performance (Hoffman, Baumeister, Förster, & Vohs, 2012). Understanding why individuals have self-control failures and developing interventions to help improve self-control has theoretical and societal benefits.

The strength model of self-control (Baumeister et al., Vohs, & Tice, 2007; Vohs & Baumeister, 2016) postulates that behaviour associated with self-control outcomes is dependent on the individual having sufficient capacity or resources for self-control (Baumeister et al., 2007). Research has consistently demonstrated that, when participants perform self-control tasks simultaneously (i.e., dual-task), or in quick succession (i.e., sequentially), performance in the physical task worsens (see Hagger et al., 2010). The implication is that if you wish to perform a certain task well then avoiding preceding tasks that require self-control is desirable.

Given the applied importance of self-control, and the fact that research tends to use sequential study design where participants are exposed to a self-control task followed by a second task, then a standardized method or task that acts as the first test of self-control is clearly needed. The first self-control task should be novel, and the two self-control tasks should be unrelated (i.e., across different behavioural spheres) to reduce the likelihood of participants using well-rehearsed strategies (Alberts, Martijn, Greb, et al., 2007; Bray et al., 2008; Burkley, 2008; Englert &and Bertrams, 2012; McEwan, Martin Ginis, & Bray, 2013). A standardized self-control task would facilitate identification of individuals at risk of poor performance and as such, help develop interventions to alleviate its negative effects. There would appear to be considerable benefits to examining the strength model in athletic settings, which can require repeated acts of self-control.

3.2.1 Overview of Study

The present study consists of two experiments, designed to test the hypothesis that performance would deteriorate across consecutive self-control tasks. A key objective was to provide a direct empirical test for this hypothesis by using novel self-control tasks, where the need for self-control is not immediately obvious. In experiments 1 and 2, a modified Stroop colour-word task was completed. The Stroop effect (Stroop, 1935) is an attentional conflict task in which participants are required to resolve conflict between competing elements of a single stimulus, and is now a well-established measure of self-control (e.g., Bray, Martin Ginis, Hicks, & Woodgate, 2008; Gailliot, Baumeister et al., 2007; Hui et al., 2009; Wright, Stewart, & Barnett, 2008). This was followed by a virtual reality indoor cycling task, a novel task to participants, but one with contextual relevance to the target group (active sportspeople). Several studies have investigated the effects of self-control on sports performance, specifically with cycling performance as the dependent variable (e.g., Bray, Martin Ginis, & Woodgate, 2011; Englert &and Wolff, 2015; Martin Ginis &and Bray, 2010; Wagstaff, 2014). It should follow that experimental participants perform worse on the cycling tasks, having performed a prior self-control task (an incongruent Stroop task). The next step, in Experiment 2, was to test whether this effect would remain when an additional iteration of the cycling task was completed and the full protocol was disclosed.

3.3 Experiment 1

Consistent with the strength of self-control (Baumeister, 2007), it was hypothesised that participants in the experimental condition would record significantly slower times for the cycling performance task and perform worse on the post-cycling Stroop task, thus indicating an ego depletion effect.

3.4 Method

3.4.1 Participants

The sample consisted of forty-eight volunteer students studying undergraduate sport courses (Male: n = 38, M_{age} = 22.9 years, SD = 2.8; Female: n = 10, M_{age} = 23.2 years, SD = 2.6). Participants ranged from recreational- to regional-level athletes currently participating in a variety of sports that included football, basketball, boxing, cricket, martial arts, rugby, and trampolining. Participants all provided informed consent for their participation in the experiment, which had institutional ethical approval.

3.4.2 Measures

Depletion task. The incongruent Stroop colour-word task (Appendix B2) consisted of shapes (TRIANGLE, SQUARE, CIRCLE, DIAMOND) and words (YELLOW, BLUE, GREEN, RED) printed in a different ink colour; for example, the words "GREEN TRIANGLE" were coloured red, and appeared below a red square. When the combination was incongruent participants had to inhibit reading aloud the interfering colour words, and respond with the correct colour shape. Participants were instructed to name the ink colour and shape as quickly as possible. If incorrect descriptions were offered, participants were required to correct errors before moving on.

Control task. In the control condition, participants completed a congruent Stroop task (Appendix B1) which was similar to the incongruent Stroop task. However, the colour shapes matched the accompanying colour word, thereby reducing the need for inhibitory control. Completion time was used as a measure of self-control performance. All participants were familiarised with both of the Stroop tasks before their first trial.

Cycling task. Immediately after the Stroop task, participants performed a cycling time trial on a Trixter bike (www.trixter.net/xdream). The bikes are equipped with gears and brakes like a normal bike but unlike typical cycle ergometers, where riders do not have to navigate courses, users are able to ride a virtual course which is presented on a computer screen.

Participants rode a virtual course depicting semi-arid terrain, competing against five virtual riders. This course was purposefully selected due to its technical nature with varying terrain and undulation. This meant that “virtual” falls, and cycling off course were commonplace. As such, consistent with the approach used by Baumeister et al. (1998) the task also required the need to manage any desires to give up.

3.4.3 Procedure

Participants were told that the study was investigating the relationship between previous experience of playing sport and performance on a virtual reality cycling task using Trixter indoor cycle ergometers. The rationale for using the Trixter bikes was to offer active sport and/or exercise science students the opportunity to use a relatively novel and engaging piece of exercise equipment. The Trixter bikes were advertised as state-of-the-art indoor stationary exercise bikes that simulate riding outdoors as part of a strategy to raise interest among participants performing the test. Furthermore, this incentive served to manipulate the meaning attached to volunteering to participate in the study. Importantly, participants were not informed of the self-control focus of the study or about the sequential task design (so as to prevent participants conserving effort). When people do exert themselves on the second task, they deplete the resource even more, as reflected in severe impairments on a third task that they have not anticipated (Muraven et al., 2006).

Prior to testing, participants completed familiarisation trials for both tasks. First, participants completed a modified Stroop task. Next, participants completed a virtual reality cycling task using the Trixter bikes, which served as the dependent self-control measure. After the cycling task participants completed a second iteration of the Stroop task. All three tasks were performed in quick succession: The shorter the interim period between self-control tasks, then the greater the hypothesised ego depletion effect should be (Hagger et al., 2010).

3.4.4 Statistics and Data Analysis

The effect size metric employed was Cohen's *d*, which represents the standardized mean difference score for the experimental (incongruent Stroop) and control (congruent Stroop) groups. Effect sizes were calculated from the means, standard deviations and sample sizes for the experimental and control groups. A value of $d = 0.2$ was indicative of a small effect, $d = 0.5$ a medium effect, and $d = 0.8$ a large effect. Independent samples *t*-tests were used to compare Stroop task and cycling performance between the experimental and control group. To investigate possible reasons for differences in cycling performance between the experimental and control group, differences in heart rate responses between trials were analysed. Finally, repeated-measures analysis of variance [ANOVA] was computed to test our hypothesis that self-control ability would deteriorate by comparing differences on pre- and post-Stroop task performance.

3.5 Results

Stroop Task Performance. As expected the experimental group took significantly longer to complete the initial Stroop task (M = 22.28, SD = 4.72 s) than the control group (M = 19.38, SD = 3.90 s); $t(46) = -2.32$, $p = .025$. Although mean cycling performance times suggest an effect for prior self-control exertion between the experimental (M = 392.88, SD = 56.66 s) and control (M= 369.42, SD = 53.13 s) groups, this finding was not significant, $t(46) = -1.48$, $p = .146$. No significant differences for heart rate were found between the control (M = 142.7, SD 13.9 $\text{b}\cdot\text{min}^{-1}$) and experimental ($M$ = 143.9, SD = 25.5 bpm) groups; $t(46) = -2.11$, $p = .834$. Two-way mixed ANOVA results for Stroop task performance (see Figure 3) indicate a significant time x group interaction effect. The control group improved their performance whereas the experimental group performed worse, $F(1,46) = 5.191$, $p = .027$, $\eta_p^2 = .10$.

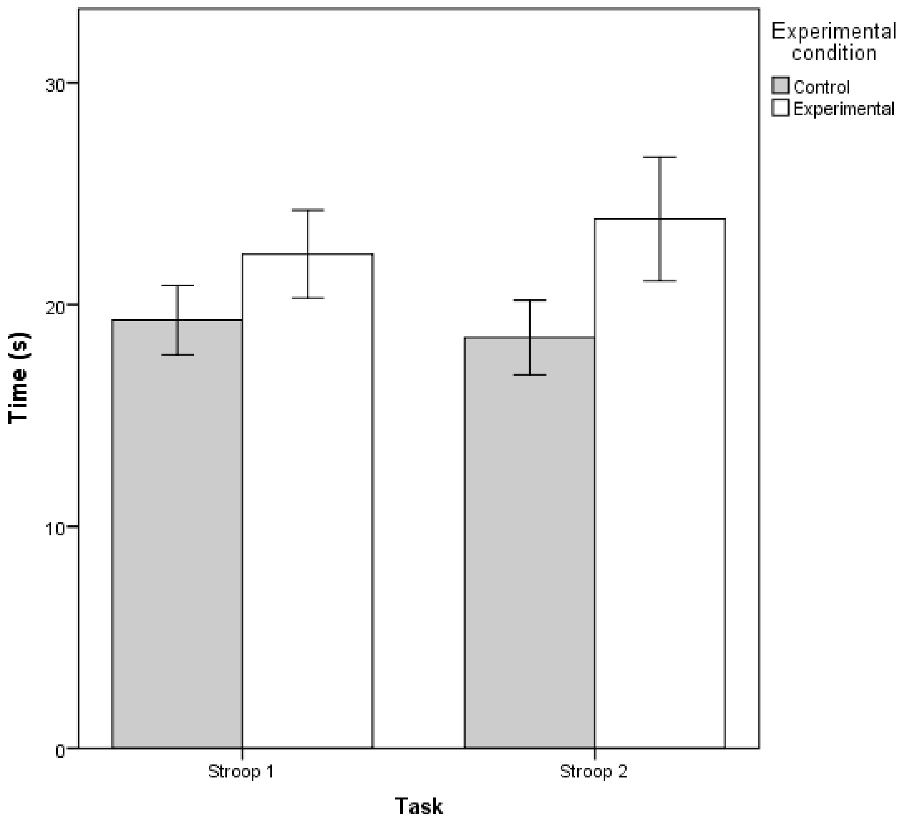


Figure 3. Mean performance times for Stroop task between groups.

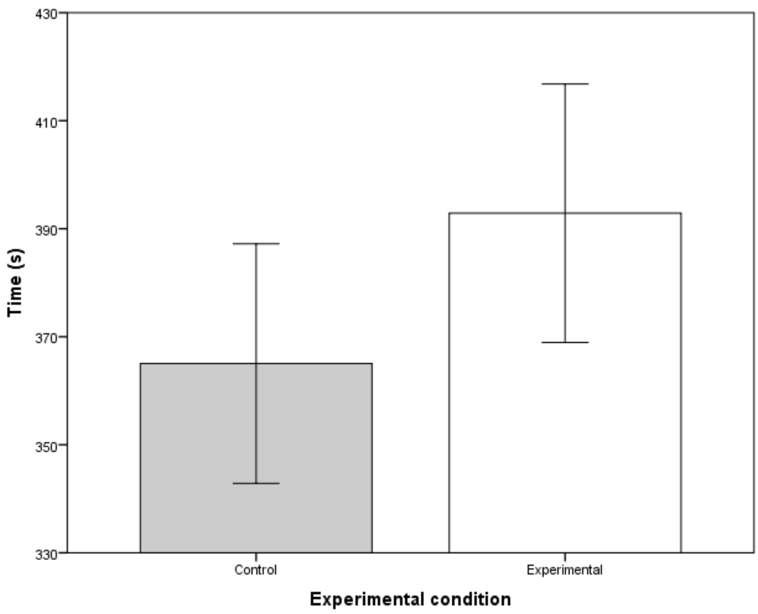


Figure 4. Mean performance times (s) for cycling task between groups.

3.6 Discussion

The aim of this study was to test the hypothesis that an initial self-control task (incongruent Stroop task) would impair performance on a second, unrelated self-control task (virtual reality cycling). As predicted, participants who performed the incongruent Stroop task recorded slower performance times than participants who performed the congruent Stroop task. Next, there should have been a significant difference in cycling performance times between the two groups. Results supported this prediction. Finally, results showed experimental participants performed worse on the second Stroop task, thus supporting the ego depletion hypothesis.

It is suggested that differences between the dependent task used in this experiment and tasks used in self-control literature (see Hagger et al., 2010) could explain contrasting findings. Following the recent proposals of Beedie and Lane (2012), it is argued that the apparent self-control failure might not be evidence of resource depletion. It is argued that performance deterioration can be explained by at least three reasons. First, identifying the need to exert self-control is not always obvious to participants. Second, deciding whether and how to exert self-control is problematic, especially given the first reason. Third, enacting a self-control strategy successfully relies on the strategy being efficient and suitable for the task.

The dependent self-control task was selected to challenge concepts that should be important to a sporting population, namely a sports task measured by completion time. Participants were recruited from a population that had already expressed an interest in sport by virtue of completing sport degrees, and being active sports participants. Participants volunteered with full knowledge of the cycle task—a task that was advertised as interesting and novel. Findings illustrated between-group differences in performance on both iterations of the Stroop task with no significant difference on the cycle task (or for heart rate). The finding that performance on the cycle task did not differ significantly between groups suggests that both groups were equitable in their investment of effort. Evidence showing no significant difference in heart rate scores between groups and mean heart rate data indicates that all participants, irrespective of group, were working moderately hard. This exercise intensity mirrors past research that has used tasks that are mildly depleting (Wright, Stewart, & Barnett, 2008).

The inclusion of the Stroop task, as a task with unknown personal meaning, was purposive. The intention was to replicate a feature (unknown meaning) used in previous research to test the strength model. Results indicate that performance was significantly slower for the experimental group on the second completion of the (incongruent) Stroop task. Performance impairments following two consecutive acts of self-control have consistently been interpreted as evidence of a limited resource explaining self-control failure (Hagger et al., 2010; Baumeister et al., 1998). Thus these findings could be interpreted as evidence of depletion (Baumeister et al., 2007).

However, our results could also be interpreted as a reduction in motivation to exert self-control. That is, participants may have appraised the [Stroop] task as being inconsistent with their personal priorities (Beedie & Lane, 2012). Muraven and Slessareva (2003) proposed that motivation moderates the relationship between self-control exertion and performance outcome, which if true would corroborate the proposals of Beedie and Lane. Muraven and Slessareva demonstrated that depleted individuals persevered longer at a subsequent self-control task if they were led to believe that their persistence would be beneficial to others or to themselves. Depleted participants, who were not motivated, lowered their persistence and thus evidenced ego depletion. They concluded that exerting self-control only affects subsequent performance on tasks that require self-control and has no impact on tasks that do not require self-control.

A contrasting perspective held by Inzlicht and Schmeichel (2012) is that self-control failure in sequential task designs may not be the result of an inability to exert control, but rather of not knowing when control is actually needed. They proposed self-control exertion could dampen motivation to exert self-control in subsequent tasks which could also dull attention to cues signalling a need for self-control. In Experiment 1, participants were unaware of the demands of the cycling, including the need to exert control. As motivation to do well was not measured across the tasks it is not possible to elucidate if any motivation/ attentional shifts may have occurred. Similarly, concluding that the experimental group demonstrated ego depletion effects would be premature given the hypothetically relevant cycling task was completed just the once. Consequently, the factors explaining behaviour across the tasks were unknown. If depletion effects were beginning to be evidenced, as opposed to participants experiencing diminished motivation, or conserving resources, then these depletion effects should be identifiable in a further attempt at the cycle task (dependent task) and full disclosure of the protocol.

3.7 Experiment 2

Experiment 2 aimed to strengthen the conclusions of Experiment 1 and investigate the effects of successive self-control attempts on a second iteration of the cycling task. Following the ideas of Beedie and Lane (2012) it was hypothesised that performance would improve when participants completed a second cycling task. This prediction was based on the following logic: 1) participants would be aware of the need to exert self-control; 2) the resources required; 3) cycling performance would be construed as personally meaningful and thus elicit emotional and behavioural responses that support this process; and 4) participants would prioritise cycling performance over Stroop task performance. In Experiment 2 emotion and heart rate was assessed. Beedie and Lane argued that emotion may represent a mechanism for increasing or decreasing effort and commitment towards maintaining performance, depending on how the task is appraised: i.e., it is important to perform well. This is based on the theory that emotion is proposed to motivate action and represent goals that humans wish to attain (Nesse, 1990; Lazarus, 2000). Because emotions encompass physiological responses, increased self-regulation should be concomitant with increased physiological reactions, such as an increase in heart rate. Accordingly, the perceived importance to perform well on the cycling task, emotions, heart rate and self-rated performance were measured in experiment 2.

3.8 Method

3.8.1 Participants

Forty-three physically active (>3 days per week) volunteer participants were recruited from the university's sports campus. The sample comprised 33 males and 10 females (M_{age} = 28.8 years, *SD* = 11.7; stature: *M* = 172.9 cm, *SD* = 16.02; body mass: *M* = 74.7 kg, *SD* = 23.2).

3.8.2 Measures

Emotions. Emotion was assessed (Appendix D) using items from the Sport Emotion Questionnaire (Jones, Lane, Bray, Uphill, & Catlin, 2005) prior to (e.g., “How do you expect to feel if you perform well?” and “How do you expect to feel if you don’t perform well?’’), and post the cycling task (“How did you feel during the first bike race?” and “How did you feel during the second bike race?”). Emotions measured were “Happy”, “Anxious”, “Dejected”, “Energetic”, “Fatigued”, “Angry”, “Excited”, “Frustrated”, and “Confused”, representing a range of pleasant and high activation/ low activation unpleasant emotions (Beedie et al., 2012). Items were rated using a 7-point Likert scale with anchors ranging from 1 (*not at all*) to 7 (*a great extent*).

Task importance. Participants were asked to rate how important it was to perform well using the anchors of 1 (*not at all important*) to 7 (*extremely important*).

Heart rate. Heart rate was measured using short-range telemetry (RS400, Polar Electro Oy, Kempele, Finland).

Self-rated performance. Participants were asked to report how well they performed on a 1-9 scale where 1 = *not very well* and 9 = *very well* in response to the item “How well do you think you performed during the first [second] cycling task?”

3.8.3 Procedure

Participants were informed the purpose of the study was to explore emotional responses to virtual reality cycling. They were not informed of the self-control focus of the research. Participants provided informed consent prior to the study, which had ethical approval. As in Experiment 1 participants were randomly assigned to one of two conditions:

1) an experimental condition comprising two self-control tasks performed in quick succession and; 2) a control condition in which two tasks were performed in quick succession but only one of which required self-control (cycle task). The experimental protocol was as follows: 1) Stroop; 2) Cycle; 3) Stroop; 4) Cycle; 5) Stroop. For this study, using the same Trixter computer software as in Experiment 1, participants rode a virtual course depicting highland terrain for both trials. The highlands course was perceived to require a greater need for self-control than the semi-arid course used in Experiment 1. As there were no significant differences in cycling performance in Experiment 1, it was speculated that a more challenging course might illuminate any ego depletion effects via completion times. Participants performed the Stroop task immediately before the first cycle performance trial and immediately following the completion of each cycle trial.

3.8.4 Data Analysis

Repeated-measures ANOVA was used to test the effects of condition on cycling performance and Stroop task performance. Repeated-measures multivariate analysis of variance (MANOVA) test was conducted to compare differences in emotions between cycling task 1 and cycling task 2 and followed up with univariate tests.

3.9 Results

Descriptive statistics for Stroop task and cycling task performance are presented in Table 1. With regards to Stroop task performance both groups recorded faster completion times across the three iterations, $F(2,40) = .78$, $p = .007$, $\eta_p^2 = .22$ with no significant interaction effect, $F(2,40) = .995$, $p = .897$, $\eta_p^2 = .005$. Hence the experimental group (incongruent Stroop) did not improve at a greater rate than the control group (congruent

Stroop). There was no significant effect of condition on heart rate during the two cycling tasks, $F(1,41) = .998$, $p = .757$, $\eta_p^2 = .002$.

Table 1

Stroop and Cycle Task Time by Group

	Control		Experimental				
Variable	*M*	*SD*	*M*	*SD*	*d*	*95% CI*	
						LL	*UL*
Task 1: Stroop Time 1	19.07	6.13	23.63	5.50	0.76	0.12	1.37
Task 2: Bike Time 1	211.11	40.46	231.04	39.45	0.51	-0.11	1.11
Task 3: Stroop Time 2	17.75	5.01	22.96	4.59	1.04	0.38	1.66
Task 4: Bike Time 2	193.37	48.37	213.54	44.50	0.44	-0.18	1.04
Task 5: Stroop Time 3	16.86	5.20	21.71	3.30	1.14	0.48	1.77
Heart Rate 1	129.74	23.32	126.17	23.32	-0.15	-0.75	0.45
Heart Rate 2	133.25	21.05	135.95	18.40	0.14	-0.47	0.74
Self-Rated Performance	3.74	1.91	3.25	1.75	-0.27	-0.83	0.31

Mixed design repeated-measures MANOVA results showed there was no significant difference on emotion over time (trial 1—trial 2) between the control and experimental group, ($F(7,35) = .774$. $p = .61$, $\eta_p^2 = .13$). Follow-up univariate tests showed that there was a condition effect for the item "happy" (see Table 2).

Table 2

Univariate Tests of Emotion Between the Cycling Tasks by Group

	Cycle task 1				Cycle task 2						
	Experimental		Control		Experimental		Control				
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*	*P*	η_p^2
Angry	2.63	1.91	2.53	1.93	2.33	1.79	2.32	1.97	.68	.42	.02
Anxious	2.63	1.72	3.11	1.94	2.75	1.87	2.63	1.83	.45	.51	.01
Dejected	2.00	1.18	2.26	1.76	1.83	1.13	2.00	1.70	.71	.40	.17
Energetic	4.38	1.97	4.95	1.58	5.04	1.63	4.79	1.40	.84	.37	.02
Excited	4.17	1.74	3.89	1.97	4.29	1.63	4.16	1.83	.49	.49	.01
Fatigued	3.04	2.07	2.74	1.56	3.04	1.73	3.84	1.80	3.59	.07	.08
Happy	4.63	1.74	4.21	1.62	5.21	1.56	4.84	1.50	4.39	.04*	.10

*$p < .05$

3.10 Discussion

Results of Experiment 2 did not show support for the deleterious effects of performing an initial self-control task on either cycling performance, or changes in cycling performance between trial 1 and trial 2. Further, according Baumeister et al. (2007), participants should have recorded worse performance times in the second iteration of the dependent (cycle) self-control task. In contrast, findings demonstrate that performance improved on the second cycle task in both control and experimental groups. Further, improved performance occurred in not only the cycle task, but also across the second and third Stroop tasks. No evidence was found of the cycle task being fatiguing and, as such, it is plausible that participants perceived the tasks as not taxing their response capabilities. Previous research has successfully demonstrated performance decrements following completion of the Stroop task (Wallace & Baumeister, 2002). This task, which measures inhibitory control, has also been shown to moderate self-control behaviour (Hofmann, Adriaanse, Vohs, & Baumeister, 2013). However, researchers have used diverse behavioural tasks to tax self-control resources, and it is possible that self-control outcomes are largely influenced by the type of task performed beforehand. Because self-control is operationalised in so many different ways (e.g., persistence, inhibitory control, self-regulation, volition, etc.), self-control measures may lack sensitivity to actual self-control demands. For instance, does a cycling task, which requires persistence, tap the same underlying construct that a Stroop task is proposed to measure? Or is the Stroop task really does a measure of attentional processing speed?

3.11 General Discussion

According to the strength model (Baumeister et al., 2007) performance should deteriorate across self-control tasks. Two experiments were designed to test the ego depletion hypothesis. While results of Experiment 1 indicated differences in Stroop task performance that could be interpreted as supportive of the negative effects of self-control on performance, this result was not replicated in Experiment 2. In Experiment 2, where participants performed the cycling task twice, results showed that both groups rode faster on the second attempt. Further, results indicated participants were more motivated and happier, suggesting that an increase in positive emotional responses is associated with improved performance. It is of course possible that the strength model (Baumeister et al., 2007) is less appropriate for tasks where good performance requires increased effort, and that the process of monitoring energy levels and seeking to raise them via self-regulatory mechanisms is salient. In Experiment 2, after completing one repetition of the Stroop and cycle task, and knowing that successive tasks were to be completed, participants would have been aware of what was required to improve their performances. The findings from this study suggest that when participants are aware of the entire experimental protocol, and how performance will be assessed, any situation-induced self-control resource depletion is unlikely to cause subsequent performance impairments.

Several researchers have suggested that dispositional self-control may moderate the deleterious effects of situation-induced self-control resource depletion on subsequent task performance (Dvorak & Simons, 2009; Friese & Hofmann, 2009; Gailliot, Schmeichel et al., 2007). From this perspective, when participants are fully aware of the need to exert self-control, and can generate meaning from the task, their ability to exert self-control could be representative of their dispositional capacity to do so. When participants are unsure of the resources needed for self-control they are likely to consume resources without much thought for future performance (Beedie & Lane, 2012).

With these considerations as a backdrop, one begins to question whether previous efforts have any significant effect at all upon repeated acts of self-control. Several researchers have proposed that people conserve their resources based on past experiences and knowledge of what is to be expected (Inzlicht & Schmeichel, 2012; Muraven, Shmueli, & Burkley, 2006), supporting the idea that self-control failure can be construed as a decision to disengage from self-control rather than an inability to manage resources. However, this decision should not be interpreted as a conscious act. As Beedie and Lane (2012) contend, the allocation of resources reduces the discrepancy between the body's own regulatory mechanisms, which act without conscious thought, and a standard or ideal of behaviour, which the individual may not be aware of.

This study presents a challenge to the ego depletion hypothesis. If participants are told that they are to perform multiple self-control tasks without knowledge of what is required to produce a good performance, then are they actually demonstrating self-control failure or simply withholding effort in anticipation? As there is limited evidence to suggest people are aware of their resource availability, it is unlikely they will conserve a resource when they know little about what remains of it. Furthermore, many self-control failures are associated with established behaviours and are therefore unlikely to be novel to the individual.

Selecting a contextually relevant task was a goal of this study: as such, participants were recruited who would hypothetically find the cycling task interesting. A limitation of our approach was that the meaningfulness was unknown but assumed, and one that has previously been highlighted as a shortcoming in the literature (Beedie & Lane, 2012; Muraven & Baumeister, 2000). However, priming the individual with meaningful thoughts about how and why they want to perform in a certain manner would influence the results. It is argued that, and consistent with goal setting theory (Locke & Latham, 1990), people set goals organically and asking people to state their intentions for a task is likely to provide insight into the meaningfulness of the task without explicitly asking participants to consider it. If individuals were to be explicitly primed to consider the task's meaning, or indeed told self-control was being measured, then behaviour would represent an entirely deliberate and conscious act, thereby overlooking any automatic regulatory processes.

In conclusion it is argued that, to date, researchers have struggled to use suitable tasks with high ecological validity to simulate meaningful tasks that participants actually want to perform well. A performance measure gives no indication of the total amount of self-regulatory resources one has left, and thus has little practical value for practitioners wanting to know how depleted their client is. While the absence of baseline self-control ability is a limitation of research in this area, a baseline assessment could prime the activation of resources for future self-control tasks, highlighting a potential problem with the sequential task design. However, identifying suitable variables such as task meaningfulness and emotion does provide insight into how motivated one is to perform well, as well as their inner states, and should be considered a worthwhile line of investigation for future research.

It is proposed that a number of mechanisms influence the mediating effects of motivation and emotion upon self-control, including the possibility that dispositional tendencies and task meaning could interact to explain improved performance. In light of these proposals, future research should implicitly manipulate motivation and emotion.

Chapter 4: Simulated Crowd Noise During a Soccer Passing Test Impairs Subsequent Self-Control

4.1 Abstract

The present study was a conceptual replication of Study 1, again using two ostensibly different measures of self-control, but with a focus on investigating the efficacy of the first test of self-control using a contextually valid approach. This time, twenty-six university-level soccer players were randomly assigned to initially perform the Loughborough Soccer Passing Test (LSPT) with (self-control depletion) or without simulated crowd noise (no-depletion). Measures of accuracy, performance time, and emotion were recorded throughout. Participants then performed a subsequent self-control task—a wall squat to volitional exhaustion—with results indicating that the depletion group persisted for less time and felt more anxious. The findings from this study show support for the ego depletion hypothesis but suggest anxiety may help explain this process. However, there are some key theoretical and methodological issues that need further investigation before generalising these findings beyond the laboratory.

4.2 Introduction

Vociferous crowd noise in soccer has been shown to associate with increased mental effort, influence decision making and negatively affect performance (Balmer et al., 2007). Staying attentive to soccer-specific cues (i.e., receiving a pass from a teammate) under these conditions therefore becomes increasingly difficult over time and lapses in this ability should thus incur performance decrements. One theoretical framework that may explain this phenomenon is the strength model of self-control (Baumeister, Vohs, & Tice, 2007). In explaining how performance is compromised Baumeister et al. (2007) proposed that self-control exertion (e.g., ignoring distracting stimuli such crowd noise) draws on a shared pool of limited resources. Thus, when attentional demands increase, the availability of resources for maintaining soccer performance should decrease.

Previous research has shown that soccer performance is impaired when players have to exert self-control. Although not specifically testing the strength model, Wood and colleagues (Wilson, Wood, & Vine, 2009; Wood & Wilson, 2010) showed that penalty kicking was impaired under high anxiety conditions. Wood and Wilson (2009) showed that distracting stimuli in the form of a moving goalkeeper affected penalty kicks. Both studies have important implications for the strength model. A criticism of self-control studies is that researchers have failed to identify and test potential mediators of the depletion effect.

In their revised model of self-control, Beedie and Lane (2012) argued that the resource issue is not one of supply, but of allocation. The authors proposed that resources are allocated in accordance with whether the task is perceived as an immediate priority and thus demanding of extra effort. Specifically, they proposed that motivation and emotion are important mediators in this process. Thus, in extending the strength model to soccer performance, the present study sought to demonstrate the typical pattern of performance decline and examine whether emotion is associated with performance.

Self-control has been operationalised in a number of different ways. Previous researchers have used motor skill tasks (e.g., Englert et al., 2015; McEwan et al., 2013) and physical exercise tasks requiring persistence to demonstrate ego depletion effects (Bray, Martin, Ginis, & Woodgate, 2011; Dorris, Power, & Kenefick, 2012; Wagstaff, 2014). Research based on the strength model has shown that performance impairments occur when tasks are performed in quick succession (Hagger et al., 2010).

In the present study, university-level soccer players were asked to perform a soccer-skill test requiring self-control (performed while listening to simulated crowd noise) or no self-control (no crowd noise), and then perform the wall squat endurance test. To probe for possible mediators explaining performance, emotion felt was assessed prior to and during each test.

4.3 Method

4.3.1 Participants

Twenty-six healthy male university soccer players (M $\pm$ SD: Age = 21.04 $\pm$ 1.89 years; stature = 176.48 $\pm$ 6.58 cm; body mass = 70.03 $\pm$ 7.59 kg) participated in the study. The participants were from a range of outfield playing positions and were involved in regular training and match-play (British Universities and Colleges Sport league and cup competitions). Ethical clearance was granted by the university's ethics committee.

4.3.2 Measures and Apparatus

There were two depletion tasks used in the study. The first was the Loughborough Soccer Passing Test, which is a soccer passing test, but completed whilst listening to an audio recording simulating vociferous and abusive crowd noise. Crowd noise was taken from the Newcastle and Liverpool 2012 match at St. James' Park when Andy Carroll, a former Newcastle player and life-long supporter of Newcastle, returned. The crowd noise is abusive with a clear chant of "you let your city down" and when Carroll comes onto the pitch the crowd boo and jeer loudly. The second was the isometric wall squat where participants hold this position to volitional exhaustion. This test is designed to induce muscular fatigue and involves self-control via managing the desire to persevere (so as to attain a better performance time) against the desire to quit (so as to avoid managing the sensations associated with physical discomfort). Furthermore, it is a discrete measure for self-control as most people think that squatting primarily depends on muscular endurance. As evidenced in previous ego depletion studies, by using a distinctly different task, participants would be less likely to connect the two tasks together (Alberts Martijn, Greb et al., 2007; Muraven, 1998).

Layout of the passing test (LSPT). The Loughborough Soccer Passing Test (LSPT) (Ali, Williams, Hulse et al., 2007) was used to assess soccer players' passing accuracy (see Figure 5). The LSPT allows calculation of movement time, which is the time necessary to complete the 16 passes and to return to the central box without the penalties accumulated, as recorded by a stopwatch. However, to ensure the task is completed accurately, time is added as a penalty for errors. Penalties include: 5 s for missing the bench completely or passing to the wrong bench; 3 s for missing the target area (0.660.3 m); 3 s for handling the ball; 2 s for passing the ball from outside the designated area; 2 s if the ball touches any cone; 1 s for every second taken over the allocated 43 s to complete the test; and, as a bonus, 1 s is deducted from the total time each time the ball hit the 10-cm aluminium strip in the middle of the target. The Total Performance Time is the time necessary to complete the test after adjusting for penalties and bonuses.

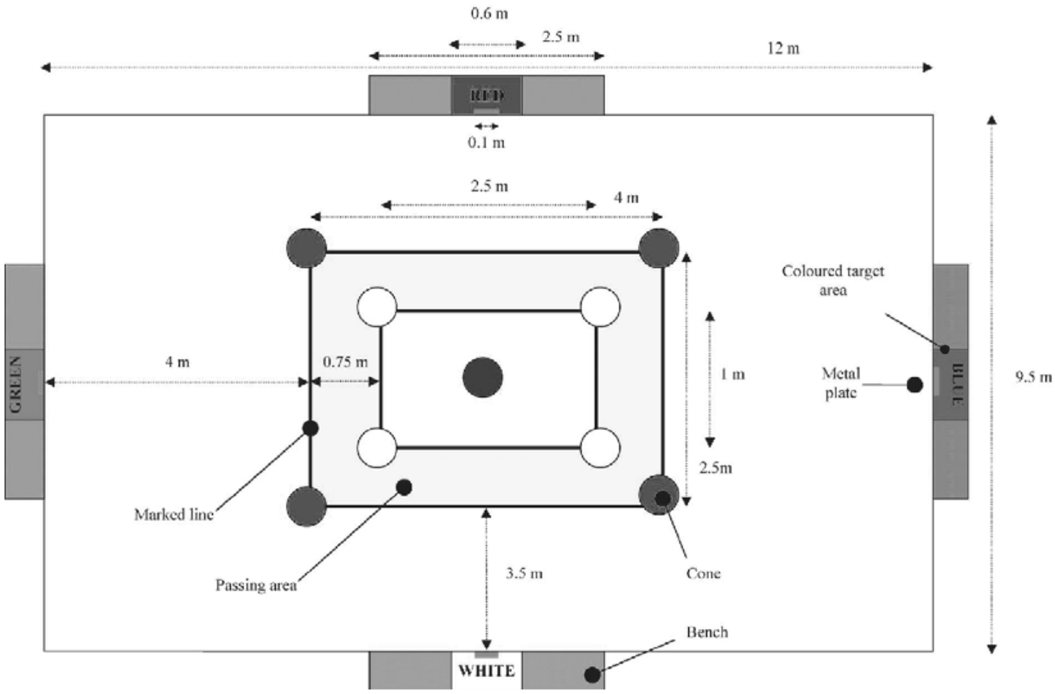


Figure 5. Loughborough Soccer Passing Test setup (Ali et al., 2007).

Task importance. Participants were asked, “How important is it that you perform well?” before completing each iteration of the LSPT, using anchors ranging from 1 (*not very important at all*) to 7 (*very much so*).

Emotional states. Participants were asked to rate their anticipated emotions prior to both iterations of LSPT. Upon completion of both soccer tests, participants were asked to rate emotions experienced during the tests. The items “Happy”, “Anxious”, “Dejected”, “Energetic”, “Fatigued”, “Angry”, and “Excited” were rated using a seven-point Likert scale with anchors of 1 (*not at all*) to 7 (*a great extent*). Five of these 7 items were taken from the same-named factors in the Sport Emotion Questionnaire (Jones, Lane, Bray, Uphill, & Catlin, 2005), with “Energetic” and “Fatigued” included to assess arousal and fatigue respectively.

4.3.3 Procedure

Participants were informed that the purpose of the study was to examine the accuracy of soccer passing performance under pressure. They were further informed that they would be performing two tests in quick succession and that they should attempt to perform each test as well as they can but given no further information.

Participants assigned to the depletion condition (Crowd Noise) completed the test whilst listening to an audio recording simulating vociferous and abusive crowd noise, whereas participants in the control condition (No Crowd Noise) performed the test without listening to the audio recording. Crowd noise was taken from the Newcastle and Liverpool 2012 match at St. James’ Park when Andy Carroll, a former Newcastle player and life-long supporter of Newcastle, returned. The crowd noise is abusive with a clear chant of “you let your city down” and when Carroll comes onto the pitch the crowd boo and jeer loudly. Both groups then performed an isometric squat against a wall, with knees bent to 90 degrees, for as long as possible.

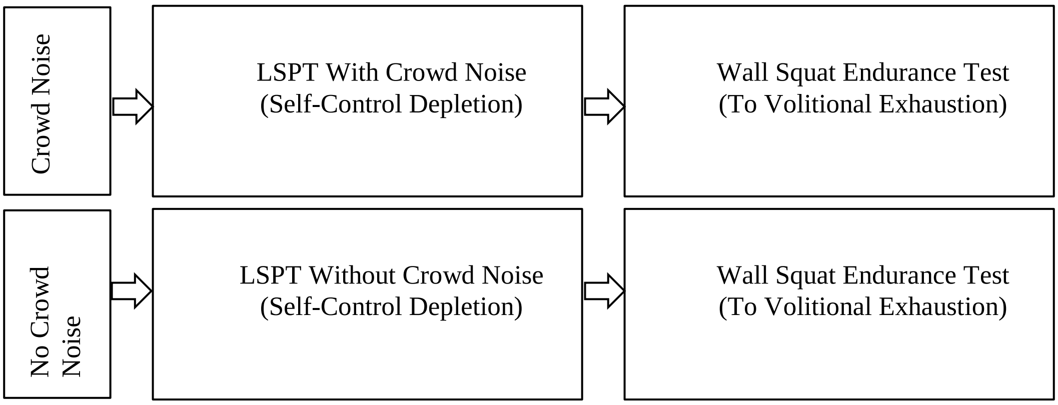


Figure 6. Schematic representation of the experimental design.

Instructions and penalties for the passing test (LSPT). Participants began with the ball (Ultimatch, Mitre Sports International, Wilmslow, UK) by the central cone, and the first examiner started timing the test—using a hand-held stopwatch (Accusplit, model 725 XP)—from the moment the ball was touched forward out of the inner rectangle. The second examiner called out the colour of the next target (i.e., order of passes). The next target was called just before the participant completed the current pass. The order of passes was determined by one of four trial orders that were randomly generated by the investigators so that each trial consisted of eight long (green and blue) and eight short (white and red) passes.

The participants were informed that passes could only be executed from within the passing area, between the set of marked lines (see Figure 5). They were also told that, upon retrieval from the previous pass, the ball had to cross two of the inner marked lines before the next pass could be attempted. Furthermore, players were informed that for best performance on the LSPT they would have to perform the test as quickly as possible while making the fewest mistakes. The first examiner stopped the clock when the last pass made contact with the target area. The examiners provided no verbal feedback to participants regarding their performance at any time during the data collection period. Players were allowed 43 seconds for test completion before they were penalised.

Instructions for the wall squat. Participants were instructed to statically hold this position for as long as possible. As soon as the participant assumed the proper position, the investigator started the stopwatch. The test was terminated when (1) the participant voluntarily stopped the test, (2) the participant failed to maintain the proper position, (3) the participant reported ill effects from the test (e.g., headache, dizziness, pain not associated with fatigue, etc.), or (4) the investigator noticed signs indicative of ill effects in the participant from the test. Participants were provided cues during the test as technique faltered away from the accepted position. Tests terminated by the investigator occurred when two consecutive corrective cues given to the participant did not result in an adequate correction in form.

4.3.4 Data Analyses

The same analyses used in Study 1 were employed, using independent *t*-tests to detect differences between subject characteristics (Crowd Noise vs. No Crowd Noise) and performance variables for each test. Next, the same multivariate analysis of variance (MANOVA) was used, with follow-up univariate tests for between-group differences on emotion. All data are presented as mean $\pm$ *SD*.

4.4 Results

Independent *t*-test results indicated no significant difference between the groups for age, $t(24) = -1.87$, $p = .074$; stature, $t(24) = .966$, $p = .344$; and body mass, $t(24) = -.908$, $p = .373$. No significant effects were found for task importance suggesting that importance to perform well remained constant across LSPT, $t(24) = -1.18$, $p = .25$ and Wall Squat tasks, $t(24) = -2.2$, $p = .83$. There was no significant difference in performance on the LSPT between the crowd noise and no crowd noise groups, $t\ (24) = 1.71$, $p = 1$. However, results indicated that the crowd noise group stopped earlier than the control group, $t(24) = 3.45$, $p = .002$ (See Table 3) on the subsequent wall squat task. These findings suggest that performance on the first task impaired subsequent task performance; a finding consistent with the strength model.

Table 3

Descriptive Statistics: Means, Standard Deviations and Confidence Intervals for Outcome Measures on LSPT and Wall Squat

Variable	Crowd Noise		No Crowd Noise				
	M	*SD*	*M*	*SD*	*d*	*95% CI*	
						LL	*UL*
Performance Scores							
MT	*62.32*	*15.19*	*53.17*	*9.27*	*0.74*	*-0.08*	*1.51*
PT	*26.99*	*18.26*	*18.53*	*12.43*	*0.61*	*-0.20*	*1.38*
TPT	*90.73*	*34.71*	*71.70*	*21.28*	*0.39*	*-0.40*	*1.15*
Wall Squat (s)	*57.62*	*20.35*	*91.20*	*27.99*	*-0.92*	*-1.70*	*-0.08*
Psychological Scores							
Importance 1	*6.42*	*1.00*	*5.86*	*1.35*	*0.14*	*-0.64*	*0.91*
Importance 2	*6.50*	*0.52*	*6.43*	*1.02*	*0.02*	*-0.76*	*0.79*

Note. LSPT = Loughborough Soccer Passing Test. MT = Movement Time was the necessary time to complete the 16 passes and to return to the central box. PT= Penalty Time was calculated from the errors committed and the bonuses scored by each player during the test execution. TPT = Total Performance Time was the necessary time to complete the test after adjusting for penalties and bonus time. Importance = “How important is it that you perform well?” (Before). CI = Confidence Interval; *LL* = lower limit, *UL* = upper limit

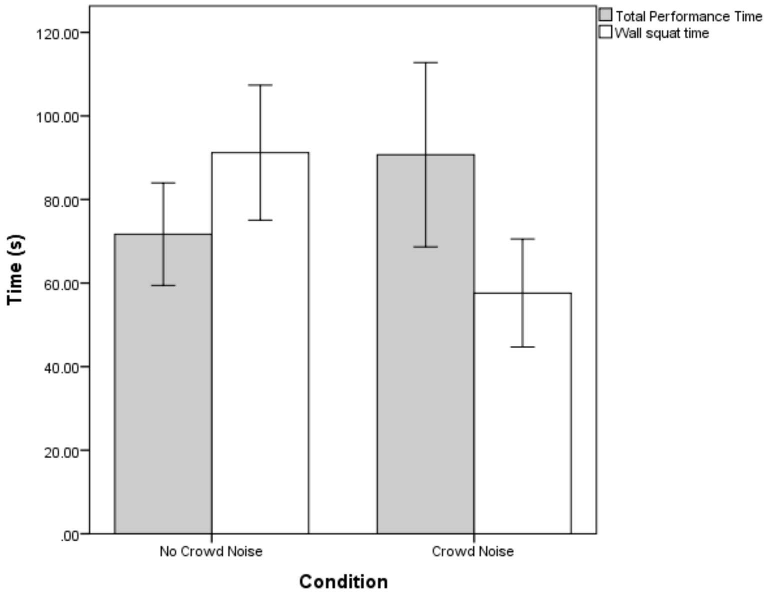


Figure 7. Mean performance times (s) between groups.

To test whether emotion could explain performance, MANOVA was conducted on emotion scores felt *during* the LSPT. Results indicated no significant difference in emotion (Wilks' Lambda = .64, $F(7,18) = 1.43$, $p = .251$, $\eta^2 = .36$), although univariate results indicated significantly higher anxiety scores in the crowd noise group (see Table 4).

Table 4

Emotion Scores During LSPT by Experimental Condition

	No Crowd Noise		Crowd Noise				
	M	*SD*	*M*	*SD*	$F_{7, 18}$	*p*	η_p^2
Happy	5.00	1.41	4.58	1.56	.51	.48	.02
Anxious	2.36	1.82	4.00	2.09	4.59	.04*	.16
Dejected	1.71	1.27	2.92	1.73	4.17	.05	.15
Energetic	4.29	1.54	4.58	1.44	.26	.62	.01
Fatigued	2.79	1.25	3.17	1.75	.42	.53	.02
Angry	2.07	1.73	2.75	1.66	1.03	.32	.04
Excited	4.14	1.10	4.83	1.59	1.70	.20	.07

$*p < .05$

4.5 Discussion

The major findings of this study were that performing a soccer skill task whilst listening to an audio file of vociferous crowd noise had a negative effect on wall squat performance, as well as associating with higher anxiety scores. In addition, there was no difference between conditions for how important it was to perform well.

Following completion of the LSPT with crowd noise, participants quit sooner on the wall squat than the control condition. This finding is in line with previous research that has tested the ego depletion effect via performance across consecutive self-control tasks

(Baumeister et al., 1998; Bray et al., 2014; Furley, Bertrams, Englert & Delphia, 2013; Muraven et al., 1998). In the present study, it was hypothesised that emotion would explain the link between performance on the two tasks. This was based on Beedie and Lane's (2012) argument that emotion is an important factor explaining whether resources are mobilised to attempt, or withdraw from, self-control.

The majority of ego depletion studies have been interpreted as evidence that self-control depletes resources. Rather than contest this, it is contended that participants actively self-regulate available resources in line with task demands. On one hand, it is possible participants who performed the first LSPT with the crowd noise decided that if they were to perform well on the wall squat then they should conserve what is left of their resources. This interpretation would support previous findings that suggest resources are conserved (Muraven et al., 2006). On the other hand, the second group, having performed LSPT without crowd noise, may have felt they did not need to conserve resources given the first test was not taxing of their resources, and as such were able to expend resources freely on the wall squat. A limitation of the present study is that pre-experimental normative data for soccer skill ability, as well as data for intensity of emotions during the task, is not available. However, a feature of ego depletion studies is that they typically use novel self-control tasks.

In their resource allocation model of self-control, Beedie and Lane (2012) argued that task appraisal was a key moderator of whether participants would engage in self-control. Thus, the present study sought to recruit a sample of soccer players for whom the self-control tasks would have some contextual relevance. Results showed that participants rated performance in the task seriously, thus potentially allowing for emotion to be intensified. Previous research has argued that emotion does not mediate self-control performance (Baumeister, DeWall, Ciarocco, & Twenge, 2005). However, evidence from sport and exercise psychology has successfully demonstrated a role for emotion in performance (Beedie et al., 2012, Englert & Bertrams, 2012).

Practical implications. The present study extends previous support for the ego depletion effect and regulation of persistence on physical tasks. Based on the findings, a broader perspective, beyond resource depletion, is needed to understand the mechanisms underlying performance across self-control tasks. The finding—that performance associated with increased anxiety—lends support to earlier findings that showed performance might be explained by changes in emotional responses. A worthwhile extension of this work would be to have players perform a further iteration of the LSPT to elicit whether participants prioritise soccer performance (contextually relevant) and if the ego depletion phenomenon dissipates across repeated self-control attempts.

Research in sport psychology indicates that coaches, athletes and sport psychology practitioners have historically provided/undertaken attentionally demanding tasks in order to improve performance, for example during activities such as desensitisation training (Bell, Hardy, & Beattie, 2013) and simulation training (Castaneda & Gray, 2007; Ryu, Kim, Abernethy, & Mann, 2013; Williams, Ward, & Chapman, 2003). However, such tasks have not typically been undertaken sequentially. As such, there is scope to examine the transfer effects of practicing self-control tasks, targeting different domains, on soccer skill performance requiring self-control. In conclusion, the finding that self-control exertion leads to worse performance must be interpreted with caution. Performance may be explained by changes in motivation and emotional responses, which determine how resources are allocated across self-control tasks. However, it may also reflect the natural tendency to want to conserve energy following physical exertion. Future research should examine performance under conditions where task demands change over time.

Chapter 5: The Influence of a Pacemaker on Psychological Responses and Pacing Behaviour During a 1600 m Run

5.1 Abstract

Pacing behaviour occurs when an individual attends to discrepancies between current performance and desired performance, and thus represents underlying self-regulation. In competitive running, a pacemaker may reduce the demand for self-regulation by controlling some of the anxiety around pace judgment. This study investigated mechanisms through which a pacemaker might be helpful to performance through examining the effects on perception, emotion and pacing behaviour. In a mixed-design repeated-measures study, nineteen well-trained runners completed two 1600 m running time trials, with ten runners having a pacemaker (paced group) who supported their individual pacing strategy to attain self-set Time goals and nine participants self-paced (control). Results indicated no differences between the groups on Time by trials. The paced group felt more anxious before running with the pacemaker, and ran a faster first lap in comparison to their mean Lap Time. The control group adopted a similar pacing strategy during each of their self-paced trials. There were no differences in goal confidence, goal difficulty or self-rated performance assessment. Post-hoc tests revealed between-trial differences in pacing strategy and RPE were located between Lap 2 and 3. A worthwhile extension of this work would be to develop and test behavioural regulation strategies that encourage runners to tolerate increased physical effort and fatigue sensations associated with a higher level of exercise intensity.

5.2 Introduction

The use of pacemakers is a common feature in distance running events, where they are instructed to run at a predetermined pace for the competing runners. In these circumstances, adopting an externally paced intensity might be beneficial by steering decision-making and behaviour towards the performance goal. This would help counter problems for runners who appear less willing to regulate physical sensations of effort and fatigue associated with a high level of exercise intensity (Herbert, Ulbrich, & Schandry, 2007). When the goal is to run as fast as possible (i.e., during a time trial), an increased willingness to exert physical effort and tolerate discomfort is desirable (Davis & Bailey, 1997).

In order to maximise time trial performance, an athlete must adopt an appropriate pacing strategy that he/ she feels provides the best opportunity to attain this goal. This will be based on factors such as knowledge of the likely task demands, previous experiences, and perceived capabilities (e.g., ability to tolerate discomfort). However, it has been demonstrated that runners often form mental representations of upcoming exercise with a low degree of accuracy. Thus, it might be hypothesised that self-selecting a pacing strategy, which requires anticipating and adopting a pacing strategy in the absence of externally information (i.e., other competitors), requires greater deliberation (Micklewright, Kegerreis, Raglin, & Hettinga, 2016) and therefore increases the amount self-regulatory resources needed (Baumeister, Vohs, & Tice, 2007).

When the exercise context deviates substantially from that anticipated, athletes must make multiple decisions about whether to increase, reduce or maintain speed. The presence of other runners is proposed to influence the role of motivation and emotion in this decision-making process, which are suggested to alter ratings of perceived exertion (RPE) and subsequent pacing behaviour (Baron, Moullan, Deruelle, & Noakes, 2011; Bath et al., 2012; de Koning et al., 2011; Marcora & Staiano, 2010). Thus, a pacemaker might reduce the amount of behavioural regulation needed in normal competitive situations.

Few studies have examined the influence of a designated pacemaker on psychological responses during running. While Bath et al. (2012) examined performance, pacing strategy and RPE during a 5 km time trial with a pacemaker, the authors did not disclose the pacemaker's role to the participants. Despite no overall differences in performance times, all 11 participants believed that they had run *faster* - and 9 said it felt *easier - with the pacemaker*. Although the researchers did not investigate performance intentions they suggested that practically it may be important to performance to know that someone is running to try to "push" you to achieve a faster time. Because conditioned beliefs about performance strongly influence early pacing behaviour (Micklewright et al., 2010), a pacemaker could act as an agent to modify how the athlete perceives forthcoming competition; by influencing emotions, perception and pre-planned pacing strategy.

An emotion involves physiological responses (i.e., increased arousal and muscle tension) and has specific action tendencies, which may mediate subsequent behaviours (Beedie & Lane, 2012; Beedie, Lane, & Wilson, 2010; Hanin, 2010; Lazarus, 2000). In the context of achieving a running goal, if an individual believes that the goal is too difficult and therefore unlikely to be attained then unpleasant emotions such as sadness, anger, and anxiety are likely to emerge. Conversely, if the individual is confident that the goal will be achieved then happiness is likely to be experienced. If attaining the goal involves reducing a large discrepancy between current performance and the standard required to reach the goal, then emotions such as anger, anxiety and excitement might prompt a physiological response to facilitate the action in question (Lazarus, 2000).

Previously Wilson, Lane, Beedie and Farooq (2012) found that, in response to negative feedback, efforts to regulate emotion were associated with changes in pacing behaviour during 10-mile laboratory cycling. For example, an increase in anxiety, which emerged in response to participants being told they were behind schedule, associated with increased ventilation, lactate production and heart rate. Then, in an extension of Beedie et al's (2012) findings, Lane et al. (2016) examined the effect of emotion regulation strategies on 1600 m running performance. Using a within-subject design, the authors compared the effects of running when experiencing high intense unpleasant emotions against running when feeling calm (low intense pleasant emotions). They reported that intense unpleasant emotions such as high anxiety associated with a fast first lap, two slower laps and a faster final lap. Importantly, they found no significant difference in running time between intense unpleasant emotions conditions. They suggested that the high- intensity unpleasant emotion condition could lead to faster performance if the pacing strategy adopted followed a more consistent pattern as suggested by Foster et al. (2014). The authors suggested that the use of a pacemaker(s) could be an effective strategy to counteract the anxiety experienced from pace judgment by providing ongoing external feedback (Lane et al., 2016). Accordingly, the purpose of this study was to investigate the effects of a designated pacemaker on perception, emotion, and pacing behaviour during a 1600 m run. It was hypothesised that the presence of a pacemaker would alter the pacing behaviour of the athlete compared to the self-paced trials by influencing performance expectations, emotion and perception.

5.3 Method

5.3.1 Participants

Nineteen well-trained endurance runners (16 male, 3 female; M_{age} = 29.4 years, *SD* = 8.8) were recruited from local running clubs to participate in the study. "Well-trained" was defined as taking part in regular, structured training (>5 days per week) for competition, for a minimum of two years. All participants had experience of running on an outdoor 400 m track. The study protocol was approved by the institution's local ethics committee. Prior to data collection, all participants provided written consent.

5.3.2 Measures

Self-set goal time, goal confidence and goal difficulty. Before each trial, participants were asked to indicate the time (mins; seconds) they are setting as a performance goal for the trial. They were also asked to rate the confidence they have for achievement of the goal (0 = *cannot do at all* to 10 = *highly certain can do*) (Bandura, 2006) and its difficulty (1= *not at all* and 10 = *extremely*).

Emotions. Participants completed the same 7-item measure of emotions previously used by Lane et al. (2016) before, and after, each 1600 m. Emotion was measured using the items "Happy", "Anxious", "Dejected", "Energetic", "Fatigued", "Angry", and "Excited", using a 7-point Likert scale with anchors of *not at all* (1) to *extremely* (7).

Performance. Performance was measured objectively in terms of finish and lap time.

Self-rated performance assessment. Post trials, participants were asked to rate how well they performed on a scale from 1 (*not very well)* to 10 (*extremely well)*; and indicate a reason for successfully/ not attaining their goal time.

Rating of perceived exertion. Post trials, participants were also asked to rate how each lap felt: 1) “Too fast”; 2) “About right”; 3) “Too Slow” and to rate perceived exertion (RPE) during each lap from 1 (*no effort at all*) to 10 (*maximal effort*) (CR-10; Borg, 1982).

5.3.3 Procedure

Participants were informed that the purpose of the study was to examine pacing strategies during 1600 m running but were not made aware of the aims and hypotheses. They were also informed they would be performing two consecutive 1600 m TTs, separated by a ten-minute rest period, and that they should attempt to perform each trial as maximal efforts. Participants were instructed to arrive for testing in a rested and fully hydrated state, having refrained from eating for at least 3 hours, and having avoided strenuous exercise in the preceding 24 hours. Testing was not conducted if wind speed > 2.0 $m \cdot s^{-1}$ was measured (Jones & Doust, 1996).

Before testing, participants completed a 5-minute self-paced warm-up followed by a 5-minute self-selected stretching routine (Smith & Jones, 2001). Participants performed two consecutive 1600 m TTs on an outdoor 400 m track, with runs hand-timed to the nearest second. All participants first completed a 1600 m TT following a self-selected pacing strategy. Participants were then randomised to either a paced or control group. The control group were asked to perform a second self-paced trial whereas the paced group were asked to run a second 1600 m TT with another runner (pacemaker). Both pacemaker and participants were allowed to wear their own watches to help pace themselves. In addition, the first author provided time feedback every 400 m. During the trials, split times were recorded every lap at 400, 800, 1200 and 1600 m. The mean lap time was then calculated.

Pacemaker. In the paced group, an experienced runner acted as a pacemaker to help each participant achieve his/ her performance goal. Participants were instructed to request the pace they would like the pacemaker to run at (e.g., run at their mean pace from the first trial for each lap). To replicate normal competition, the pacemaker and participants were allowed to wear a watch, and were given time splits every 400 m lap.

5.3.4 Data Analysis

Data analysis in the present study sought to test hypotheses that running with a pacemaker would influence psychological responses, which would lead to improved performance. With a small sample size, the strategy was to calculate delta scores for differences in psychological responses and performance between trials, and to analyse data using a simple independent samples *t*-test. Overall Performance Times, Goal Confidence, Goal Difficulty, Self-Rated Performance Assessment and Emotion were assessed using independent samples *t*-tests on delta scores for differences between trials.

A series of two-way (Condition x Lap) mixed repeated-measures ANOVA were also used to assess the lap speeds and RPE across each 400 m distance, with repeated contrast tests conducted to establish significant changes between successive measurement points. A similar analysis was used to assess the pacing strategy (running velocity) when expressed in relation to the average running velocity recorded for the trial. Linear regression analysis, using Pearson's correlation coefficients (r), was used to indicate the strength of the relationship between ideal and planned pacing strategy, goal time and actual performance time, RPE and lap times, and perception of pacing strategy and RPE. Statistical analysis was conducted using SPSS statistics software Version 22.0 (SPSS Inc. Chicago, IL). Significance was accepted at $P < .05$. Data are presented as means ± SD.

5.4 Results

Overall performance time (1600 m) for all trials. Independent samples *t*-test results on differences between trials revealed no differences between groups, $t(17) = -0.86$, $p = .40$, $d = 0.40$).

Table 5

Overall Performance Times for Both Trials

	Trial Times (s)											
	Control (n = 9)						Paced (n = 10)					
	Predicted		Actual				Predicted		Actual			
	M	*SD*	*M*	*SD*	*r*	*p*	*M*	*SD*	*M*	*SD*	*r*	*p*
Trial 1	287	18	293	20	.86	.003**	326	19	324	29	.96	.001**
Trial 2	290	22	293	20	.85	.001**	329	36	328	30	.96	.001**

$^{**}p < .01$

Split speeds across split distances of 400 m distance for all trials. A two-way mixed repeated measures ANOVA with contrasts between Group x Lap Time showed significant differences at Lap 1—2, $F(1,17) = 4.88$, $p = .04$, $\eta_p^2 = .22$, and between Trial x

Lap Time at Lap 2—3, $F(1,17) = 4.84$, $p = .04$, $\eta_p^2 = .22$ As demonstrated in Figure 8, both groups adopted a fast-start pacing strategy, before slowing down.

Emotion changes in precompetitive emotion across trials. The paced group reported feeling more anxious before Trial 2 ($p = .04$).

Self-Ratings

Self-set goal time versus actual time. Self-set goal time and actual times correlated significantly for the two groups across Trial 1 (control: $r = .86$, $p = .003$; and paced: $r = .85$, $p = .001$) and Trial 2 (control: $r = .96$, $p = .000$; and paced: $r = .96$, $p = .000$).

Goal confidence, goal difficulty and self-rated performance assessment. Both groups reported no significant differences for confidence in being able to achieve their goal time (Table 2), $t(17) = .12$, $p = .91$, $d = 0.67$), goal difficulty, $t(17) = -1.24$, $p = .23$, $d = 0.57$) or self-rated performance assessment $t(17) = 1.69$, p = .11, d = 0.76.

Rating of Perceived Exertion. Ratings of perceived exertion increased for each lap increased significantly ($p < .001$) during each trial, although this finding was not significant between trials, $F(1,17) = 3.371$, $p = .084$, $\eta_p^2 = .165$, or groups, $F(1,17) = 3.066$, $p = .098$, $\eta_p^2 = .153$ (see Figure 9). Repeated contrasts for comparisons against previous lap data showed a significant difference for change in RPE scores by Trial between Lap 2 and Lap 3 $F(1, 17) = 4.73$, p = 0.73, $\eta_p^2 = 0.22$.

Table 6

Differences Between Trials by Group for Overall Performance Times, Goal Confidence and Difficulty, Self-Rated Performance, and Emotion

	t(17)	Sig. (2-tailed)	95% CI	
			LL	UL
Overall Performance Time	-0.86	0.40	-15.33	6.44
Goal Confidence	0.12	0.91	-2.28	2.55
Goal Difficulty	-1.23	0.23	-2.37	0.62
Self-Rated Performance Assessment	1.68	0.11	-4.00	3.60
Happy	-1.87	0.08	-1.56	0.09
Anxiety	2.28	0.04*	0.11	2.91
Dejection	-0.53	0.61	-0.50	0.30
Energetic	-1.34	0.20	-2.66	0.60
Fatigue	0.30	0.77	-1.07	1.42
Anger	0.42	0.68	-0.66	1.00
Excited	0.56	0.58	-1.13	1.95

*p < .05

Table 7

Repeated Measures Comparisons of Emotion Pre and Post Time Trial 1

	Experimental condition						
	Control		Paced				
	M	*SD*	*M*	*SD*	*F*	*p*	η_p^2
Pre-Time Trial 1							
Happy	5.22	1.39	4.30	1.89	1.44	.25	.08
Anxious	4.22	1.20	3.10	2.08	2.01	.17	.11
Dejected	1.11	.33	1.80	1.87	1.18	.29	.07
Energetic	4.89	1.45	4.00	1.76	1.42	.25	.08
Fatigued	2.44	1.42	2.50	1.43	.01	.93	.00
Angry	1.11	.33	1.10	.32	.01	.94	.00
Excited	4.44	1.24	4.50	2.07	.01	.95	.05
Post-Time Trial 1							
Happy	4.67	1.87	5.30	1.16	.81	.38	.05
Anxious	1.56	.88	1.80	1.55	.17	.68	.01
Dejected	1.67	0.71	1.60	0.97	.03	.87	.00
Energetic	4.44	1.94	3.90	1.10	.58	.46	.03
Fatigued	3.44	.88	3.80	1.14	.57	.46	.03
Angry	1.67	1.12	1.40	.70	.40	.54	.02
Excited	3.78	1.72	4.20	1.81	.27	.61	.02

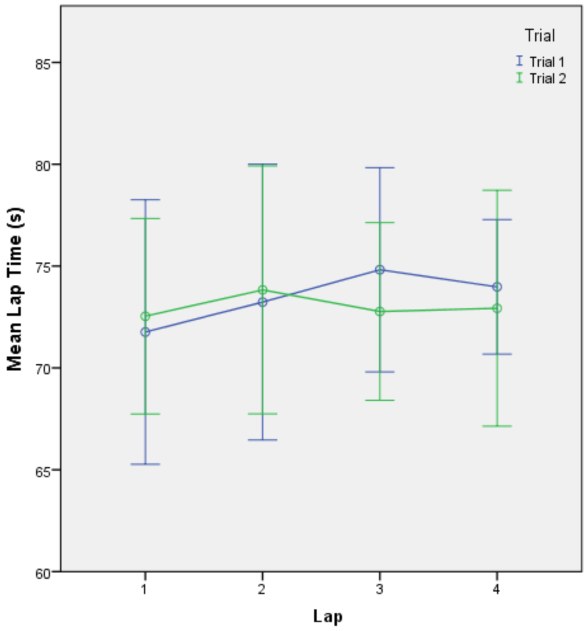
Table 8

Repeated Measures Comparisons of Emotion Pre and Post Time Trial 2

	Experimental condition						
	Control		Paced				
	M	*SD*	*M*	*SD*	*F*	*p*	η_p^2
Pre-Time Trial 2							
Happy	4.89	1.27	4.70	1.57	.08	.78	.01
Anxious	3.11	.93	3.50	1.65	.39	.54	.02
Dejected	1.11	.33	1.70	1.64	1.12	.31	.06
Energetic	4.56	1.81	4.70	1.34	.04	.84	.00
Fatigued	2.67	.71	2.90	1.60	.16	.69	.01
Angry	1.44	.73	1.60	1.07	.13	.72	.01
Excited	4.56	1.59	4.20	1.69	.22	.64	.01
Post-Time Trial 2							
Happy	5.44	1.13	4.60	2.07	1.18	.29	.07
Anxious	1.11	.33	1.60	.84	2.64	.12	.13
Dejected	1.78	1.09	1.80	1.23	.00	.97	.00
Energetic	3.00	1.41	3.70	1.49	1.09	.31	.06
Fatigued	3.22	1.48	3.20	1.03	.00	.97	.00
Angry	1.56	1.01	1.60	1.07	.01	.93	.00
Excited	3.67	1.41	4.10	2.18	.26	.62	.02

Repeated-measures MANOVA showed no overall effect for emotion across trials, Wilks' Lambda (6,040) = .010, p = .311, η_p^2 = .990.

A



B

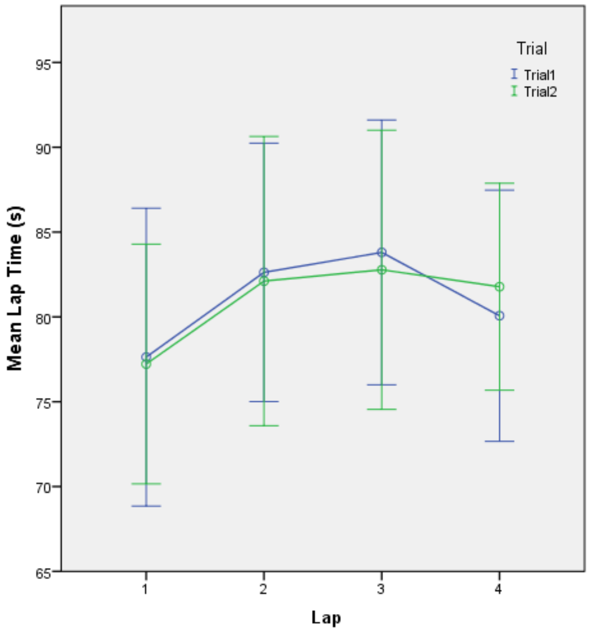
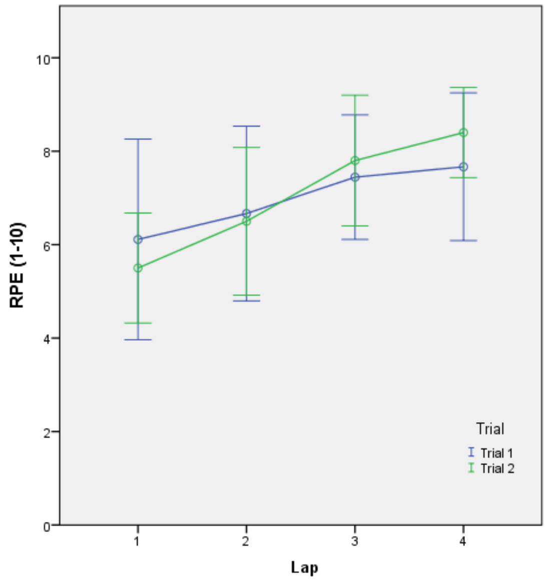


Figure 8. Pacing profiles during trial 1 and trial 2 for self-paced (A) and paced groups (B). Error bars represent $\pm$1 SD.

A



B

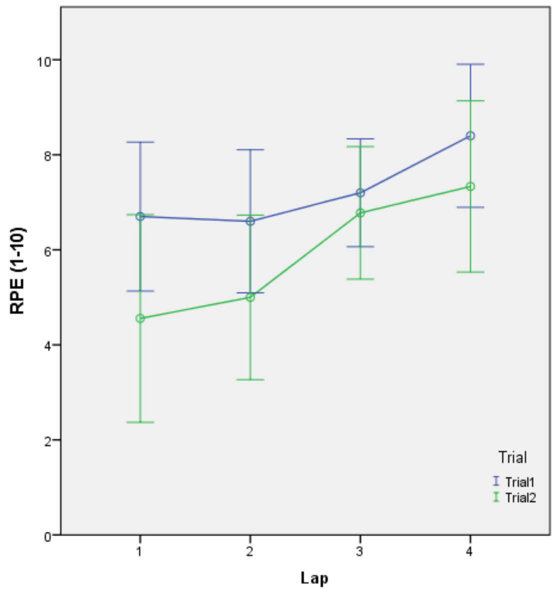


Figure 9. RPE values for each lap during both time trials for self-paced (A) and paced group (B). Error bars represent ±1 SD.

5.5 Discussion

The primary aim of this study was to examine the influence of a pacemaker on psychological responses during a 1600 m run. It was hypothesised that a pacemaker would act as an agent to counteract anxiety, by reducing the amount of self-regulatory effort associated with pace judgment (Lane et al., 2016). It was expected this would result in a change in perception, emotion and pacing behaviour. Findings support this contention as the paced group, despite rating greater anxiety before their paced trial, adopted a similar fast-start strategy to their self-paced trial, but ran a more consistent overall pacing strategy. In other words, they did not experience the same reduction in running speed during their paced trial. Post-hoc tests revealed that the increase in pace in Lap 3 associated with a similar increase in perceived exertion. However, there were no differences in goal confidence, difficulty or self-rated performance assessment. Although the addition of a pacemaker among the paced group did not improve their overall performance, this should not detract from the value of these findings as they cast light on the nature of self-regulation.

The self-paced group followed a strategy of a fast first lap followed by two slower laps and fast last lap, which is characteristic of one-mile running (Foster, de Koning, & Thiel, 2014), which is the strategy followed by the self-paced group. There are a number of possible explanations for this finding. First, the controls learned from the first trial to pace themselves whereas participants in the paced group had two novel runs. As the participants were experienced runners the two trials were learning experiences. Therefore, whilst the paced group had another athlete helping them decide the pace, the control group used memories of the previous performance. Given the close relationship between goal time and performance for the control group, it suggests that this acted as a blueprint for the second run.

Second, when athletes self-pace, they may subconsciously conserve effort prior to and during exercise (St. Clair Gibson & Noakes, 2004). Both the control and paced group experienced a linear increase in RPE during both trials, a finding consistent with previous research investigating RPE during running trials (Bath et al., 2012). The intensity of RPE at the final lap was close to the maximum score. Research suggests that people vary their behaviour by modulating somatosensory inputs so as to adapt to environmental disturbances on a trial-by-error basis rather than relying on learned action patterns (Marken & Powers, 1989). The self-paced group demonstrated less variation between fastest lap time and average lap time (T1 = 1.7%; T2 = 1%) with a larger variation evident for the paced group (T1 = 3.6%; T2 = 3.3% (see Figure 8). In addition, there was a larger difference between the slowest and fastest for the paced group (T1 = 6.8% vs. 3.4%; T2 = 4.8% vs. 2.3%).

As Thiel et al. (2012) noted, athletes often do not self-select their pace but rather adjust to the speed enforced by the leader. Whether the adjustments can be maintained will depend on several factors including comparison of previously stored schema. The self-paced group would have had a schema for the second trial whereas the paced group would have had to continually self-regulate during their trial by distancing themselves or running in closer proximity to distinguish between their own and the pacemakers pace. This strategy is typical of competitive races, whereby athletes drop off to maintain a more stable pace so as to avoid a massive and progressive reduction in running speed.

It was expected that a pacemaker would help promote adaptive and pleasant emotions by offering a strategy to achieve goals (Beedie et al., 2012). Beedie et al. used strategies to prevent goal attainment such as deceptive feedback. Results demonstrated that following a pacemaker associated with significantly higher anxiety and lower happiness. It might be that participants feel happier and less anxious when they self-select and implement an appropriate pacing strategy. Perhaps when athletes self-select their pacing strategy they are inherently conservative and repeated self-paced running builds a more robust pacing template. When athletes have to run with others then they must decide where to direct their attention: to either their own perceptual responses (e.g., perceived effort, breathing, etc.) or to other stimuli (e.g., another runner). Running with another runner may interfere with the higher level cognitive processing (e.g., memory of previous pacing strategies, motivation, etc.) that affects whether one can enact goal-directed behaviour. It is quite possible that the participants did not fully trust the pacemaker's ability to accurately pace their run which is why they felt more anxious. Athletes should therefore consider how best to integrate these factors if they are to successfully counteract the tendency to start fast with others, as a fast start is not always associated with improved performance (Hanon & Thomas, 2011).

Conclusions and future recommendations. The self-pacing strategy task used in this study was hypothesised to be more cognitively challenging than an imposed pacing strategy task (i.e., self-pacing requires more planning and monitoring). If runners are to take advantage of the proposed benefits of running with others (Pugh, 1971; Davies, 1980) and the proposed ergogenic effect of an individual pacemaker, then they should practice self-pacing under these conditions. The athletes in this study struggled to enact their intended behaviour, despite being trained runners with knowledge of the distance and prior experience of track running. After setting a goal, an athlete must successfully initiate action that supports goal-directed behaviour. However, this ability depends on how well the athlete is able to shield the goal from distractors. Following on from the results in the current study, it is argued that athletes are capable of regulating their energetic resources (via pacing) but, in order to take advantage of running with others (e.g., motivation, energetic, etc.), they should focus on developing psychological strategies to cope with increased anxiety.

In conclusion, the present study showed that the use of a pacemaker as a novel and useful technique for optimising pacing strategy during 1600 m track running did not improve overall performance. However, the paced group did run a slower first lap. The concept of self-pacing appears to facilitate greater self-awareness and can be seen as a useful strategy to reduce regulation effort. Athletes will typically self-pace their efforts during training and arguably develop strategies to respond with situational demands during competitions whilst exercising within the confines of their physical capabilities. Whilst a pacemaker could offer a potential performance benefit, the findings showed that participants experienced greater anxiety when being paced. The evidence in this study suggests that the introduction of a pacemaker might interfere with intuitive self-pacing, and therefore a tactic that does require practice.

Chapter 6: Effect of Consuming a Sports Drink on Performance in a Series of Physical and Cognitive Self-Control Tasks

6.1 Abstract

Intense physical exercise such as interval training requires self-control to ensure performance is maintained across the entire session. One solution for this is to consume glucose, which has been shown to moderate self-control via increased motivation and physical effort. The present study utilised a within-subject multiple treatment design to examine the effect of consumption of a carbohydrate-electrolyte solution (sports drink) on repeated self-regulatory exercises. Five runners (mean + SD age = 42.2 ± 7.5 years) performed a single high-intensity interval training (HIT) session comprising 8 x 800 m repetitions on a 400 m outdoor running track, once a week, for six weeks. Repetitions were interspersed with a 2-minute recovery period in which participants were instructed to perform a modified Stroop colour-word task, and drink ad libitum from either 500 ml of plain water or sports drink. Participants also completed a brief measure of emotions between repetitions. The data have a two-level hierarchical structure with weeks at level 1, nested within individuals at level 2. Three individual-level characteristics are considered as explanatory variables: gender, drink type and emotion. Results revealed that females recorded faster average completion times for both running repetitions and Stroop tasks when consuming the sports drink. In addition, when the terms “happy” and “anxiety” were factored into the model, analyses showed that they were significantly happier when consuming water and more anxious when consuming sports drink. Future research should extend these findings by examining the association between ergogenic aids, emotions and performance.

6.2 Introduction

Self-control or self-regulation is widely considered to be important for success across a variety of life domains (Tangney, Boone, & Baumeister, 2004). Yet, people frequently experience lapses in self-control, which compromises their ability to exert further self-control. One prominent explanation for this phenomenon, known as the strength model, is that self-control depletes some kind of inner resource that is limited in its supply (Baumeister, Vohs, & Tice, 2007). The strength model has attracted attention in the field of sport and exercise psychology where researchers have been able to demonstrate that that prior self-control exertion negatively affects sports performance (for a review, see Englert, 2016). For example, Englert and Bertrams (2014) showed that asking participants to override their habitual writing tendencies on a word transcription task impaired their sprint start reaction times. Similarly, Pageaux, Lepers, Dietz, and Marcora (2014) found that exerting inhibitory control on an incongruent Stroop task for 30 minutes impaired subsequent 5 km treadmill running performance. Wagstaff (2014) showed that emotional suppression while watching an upsetting video led to worse performance on a 10 km indoor cycling time trial. The question then is: how does one counteract self-control depletion effects?

One of the more novel and intriguing entailments of the strength model is that it might be possible to overcome depletion effects by replenishing resources, exogenously. An emerging perspective is that glucose moderates self-control via non-metabolic pathways, even when it is not ingested (Molden, 2012; Sanders, Shirk, Burgin, & Martin, 2012). For example, Sanders et al. (2012) found that rinsing with glucose-based lemonade—as opposed to a placebo solution—improved incongruent Stroop task performance. Researchers in sport have reported similar performance enhancing effects following glucose rinsing. For instance, Chambers, Bridge, and Jones (2009) demonstrated that participants who briefly rinse their mouths with, but do not ingest, carbohydrate solutions during cycling time trials showed significant increases in performance as compared with participants who rinsed with placebo solutions containing non-carbohydrate sweeteners. The proposed mechanism for this non-energetic effect is that glucose acts a signal that helps sustain the central drive required to maintain physical effort. Specifically, stimulation of glucose receptors can influence the perception of effort, motivation, mood and motor output (Murray, 2007). These proposals could have important implications for self-control. Even if glucose is not the self-control resource, it may still have an effect on psychological and behavioural processes implicated in self-control. Thus, extending Beedie and Lane's proposals, glucose ingestion could influence emotion—which acts as a catalyst for increased energy supply—and thereby determine whether motivation to self-control is increased, maintained, or reduced. Thus, examining the mediating role of changes in emotion could offer insight as to how carbohydrate affects self-control.

Therefore, the present study sought to test the above proposals, and examine whether sports drink consumption could reverse the typical pattern of behaviour observed across sequential task designs (Hagger et al., 2010). Sport drinks, otherwise known as carbohydrate-electrolyte solutions, typically comprise a mix of glucose and fructose, and are frequently used in prolonged endurance exercise to aid performance (Coombes & Hamilton, 2000). To test this proposal, five endurance runners were asked to perform high-intensity interval training (HIT) once a week, for six weeks. In the interim rest period between repetitions, participants were instructed to: 1) complete a Stroop colour-word task and brief measure of emotion, and; 2) freely consume 500 ml of either plain water (WAT) or a sports drink (SPD).

HIT involves repeated short (<45 s) or long (2-4 min) high-intensity exercise bouts alternated with recovery periods of light exercise or complete rest (Billat, 2001) and is used by middle- and long-distance runners to enhance performance. An important aspect of this type of training is the ability to modulate fatigue-related interoceptive cues. Therefore, individuals must focus on self-pacing each bout, which is considered within the context of the available recovery. The Stroop task (Stroop, 1935; see MacLeod, 1991, for a review), a measure of inhibitory control, is the prototypical definition self-control task (Gailliot et al., 2007; Richeson, Baird, Gordon, Heatherton, & Wyland, 2003; Hagger et al., 2010). Building on the recommendations of Beedie and Lane (2012) and Heneghan et al., (2012), the present study provides an ecologically valid test of the effectiveness of a sports drink on real-world athletic performance.

To take full advantage of the available longitudinal data, the study used multilevel modelling to interpret Stroop and running performance-associated changes with/out carbohydrate ingestion. Multilevel regression modelling (also known as hierarchical linear modelling) is a statistical technique that describes both the individual mean response and its variation around the group mean. It is an extension of ordinary multiple regression analysis when data have a hierarchical or clustered structure. In repeated measurement data sets, the hierarchy may be seen as a repeated measurement occasion (defined as level 1) clustered within the individuals (defined as level 2); that is when there are repeated measurements over time on a number of different people. Change was analysed (that is, improvement) by specifying average repetition time as the response (outcome variable). Thus, when runners are assessed on more than one occasion, two levels of variability account for a single runner's departure from their fitted growth trajectory: the measured occasion variability (level 1) and the underlying population response (level 2).

It was hypothesised that consumption of a sports drink would associate with a positive belief about performance and thereby be associated with positive emotion. Thus, it was expected consumption of a SPD to improve both HIT and Stroop task performance (as assessed by a faster average repetition

6.3 Method

6.3.1 Participants

Five amateur endurance runners (three male, two female; M_{age} = 42.7 years, *SD* = 7.2) volunteered to take part in this study. Inclusion criteria required that participants were over the age of 35 years, regularly performed HIT training (at least one session per week) and had experience of running on an outdoor 400 m track. Participants were instructed to maintain their pre-study volume of training and to replace one scheduled HIT session with a HIT performed on a running track. Participants provided written informed consent to participate in the study, which received approval by the institution's research ethics review committee. Participants were made aware that the purpose of the study was to investigate the effects of a sports drink on running performance and cognitive ability.

6.3.2 Experimental Design

This study used a small-n repeated measures within-subject design using all the participants in both treatment conditions. Once a week, for six weeks, participants were asked to perform a HIT session in which they completed a Stroop colour-word task and brief measure of emotion, and were instructed to freely consume 500 ml of either plain water (WAT) or a sports drink (SPD). Participants were randomly allocated (www.random.org) to 3 visits for each of the two experimental conditions (sports drink versus water). This procedure was followed to exert control over the training effects that consecutive sessions elicits as well as other confounds including demotivation (Dugard, File, & Todman, 2012).

6.3.3 Materials

Sports drink. The “sports drink” was a solution of a commercially available carbohydrate-electrolyte formulation (isomaltulose, 13 g; sodium, 43 g) mixed according to the manufacturer’s instructions. At the end of each session, the first author noted the volume of carbohydrate-electrolyte solution remaining in the 500 ml plastic bottle.

Interval running. Participants recorded every training session with a wrist-worn heart-rate monitor (RS400, Polar Electro Oy, Kempele, Finland) which provided feedback in the form of heart rate response ($b \cdot min^{-1}$) and elapsed time (min: sec). For the completed session, mean performance time (min: sec), mean heart rate ($b \cdot min^{-1}$) and velocities ($km \cdot h^{-1}$) were calculated. Participants were not informed of their mean performance time until all sessions had been completed.

Emotion. The following emotional states “Happy”, “Sad”, “Anxious”, “Calm”, “Energetic”, “Sluggish”, “Angry”, and “Guilty”, were assessed after each running repetition (“How do you feel right now?”). Four of these 8 items were taken from the same-named factors in the Sport Emotion Questionnaire (Jones, Lane, Bray, Uphill, & Catlin, 2005). The items “Calm”, “Sluggish”, and “Energetic” (added to assess the arousal dimension) and “Guilty” (added to assess dejection) were adopted from Lazarus (2000). Emotional states were rated using a seven-point Likert scale from 1 (*not at all*) to 7 (*a great extent*).

Cognitive task. Participants completed a modified version of the classic Stroop colour-word task (Stroop, 1935; see MacLeod, 1991, for a review). The Stroop task measures inhibitory control, which is the prototypical definition of self-control (Gailliot et al., 2007; Richeson, Baird, Gordon, Heatherton, & Wyland, 2003; Hagger et al., 2010). Stimuli consisted of the shapes TRIANGLE, SQUARE, CIRCLE, and DIAMOND; and the words YELLOW, BLUE, GREEN, and RED. The task required participants to respond to each incongruent stimulus with its actual semantic meaning. For example, the words “GREEN TRIANGLE” were coloured red, and appeared below a red square and participants were instructed to name the ink colour and shape as quickly as possible (e.g., RED SQUARE). If incorrect descriptions were offered, participants were required to correct errors before moving on. Participants completed a practice trial prior to performing their first interval running session.

6.3.4 Procedure

This study was carried out during the off-season phase of training (November-December). Participants were instructed to abstain from strenuous exercise on the day before the sessions and reminded to arrive at each session fully hydrated and non-fasted. All sessions were conducted at the same location, at a similar time of day, and under the supervision of the first experimenter. Prior to each training session, all participants completed a warm-up which consisted of continuous running at low to moderate intensity in accordance with their usual warm-up habits. Next, participants completed a brief measure of emotion and then completed a track running HIT session comprising eight repetitions of 800 m interspersed with a 2-minute rest period, in which they completed a modified Stroop colour-word task. They were instructed to try and maintain the highest average running velocity they could across all the work bouts of each interval session. As participants were also asked to complete a brief questionnaire of emotional states after each repetition, they were under pressure to complete the Stroop task as quickly as possible. During the training sessions, participants received either a sports drink (SPD) containing glucose and fructose or a plain water drink (WAT). Participants were told that they could drink ad libitum from a 500 ml plastic bottle during the recovery periods.

6.3.5 Statistical Analyses

For all sessions, mean values were calculated for the measured variables. When small sample sizes are used, mixed models offer a solution to analyse within-subject differences. Gender was considered a co-variate. Instead of constructing a personal model for each subject, a model of popular behaviour is constructed, allowing parameters to vary from one individual to another, to take into account the heterogeneity between subjects. Particular care in characterizing random variation in the data is required to recognise two levels of variability: random variation among measurements within a given individual (intra-individual variation); and random variation among individuals (inter-individual variation).

Descriptive statistics (mean running and Stroop task times) were computed for each participant and each measurement occasion. Multilevel regression analyses were performed using the MLwiN software package (Version 2.0; Rashbash, Steele, Browne, & Prosser, 2005) to identify those factors (SPD versus WAT and gender) associated with running and

Stroop task performance. The data have a two-level hierarchical structure with individuals at level 1, nested within weeks at level 2. In contrast to traditional repeated-measures analyses, the number of visits is also assumed to be a random variable over time. Three individual-level characteristics are considered as explanatory variables: gender, sports drink and emotion. Average repetition time served as the outcome variable for running performance.

6.4 Results

Individual data for mean performance time (s), running velocity ($km \cdot h^{-1}$), heart rate ($b \cdot min^{-1}$), Stroop time (s), and emotion (1-7) during three sessions with sports drink and three sessions with plain water are presented in Table 9.

Table 9

Performance characteristics for each participant (Weeks 1—6: 8 x 800 m)

Variable	Participant 1		Participant 2		Participant 3		Participant 4		Participant 5	
	WAT	SPD	WAT	SPD	WAT	SPD	WAT	SPD	WAT	SPD
Mean 800 m (s)	172.9 (5.5)	169.0 (4.4)	204.2(50.4)	203.8 (7.6)	224.2 (8.7)	221.3 (8.0)	184.9 (7.3)	188.2 (12)	228.5 (8.0)	229.5 (9.7)
Velocity ($km \cdot h^{-1}$)	16.8 (0.5)	17.1 (0.4)	13.2 (2.3)	14.1 (0.5)	13.0 (0.5)	13.1 (0.6)	15.7 (0.6)	15.4 (0.9)	12.5 (0.4)	12.6 (0.5)
Heart Rate ($b \cdot min^{-1}$)	155.5 (4.3)	158.2 (2.7)	170.3 (4.3)	172.2 (2.1)	160.5 (3.9)	159.2 (4.4)	146.6 4.1)	147.3 (4.7)	148.8 (2.5)	150.7 (3.9)
Mean Stroop Task time (s)	23.50 (3.7)	21.67 (3.2)	23.06 (2.5)	21.65 (2.4)	16.65 (3.6)	16.31 (6.8)	12.82 (2.2)	12.71 (1.4)	19.38 (3.0)	24.80 (3.7)
Happy	3	2	3	3	3	4	5	4	6	4
Sad	1	1	2	2	2	1	2	3	1	1
Anxious	1	1	2	2	2	1	2	3	1	2
Calm	3	2	3	3	3	6	3	4	6	5
Energetic	3	2	3	3	3	3	5	4	3	3
Sluggish	1	1	3	4	3	4	2	3	2	4
Angry	1	1	2	2	2	1	3	3	1	2
Guilty	1	1	2	2	1	1	2	3	1	2

Note. WAT = Water. SPD = Sports Drink. Mean (SD).

The multilevel regression analysis software, MLwiN, uses the maximum log likelihood as its criterion of model assessment; that is, goodness of fit. The model considers two levels (level 1, Weeks; level 2, Individuals) of random variation that takes into account the fact that performance characteristics of individual athletes, such as their average interval time, vary around a population mean, as well as each athlete's observed measurements which vary around his or her own performance trajectory.

The multilevel regression analyses in Table 10 identified a significant improvement in running and Stroop task performance explained by drink type (sports drink versus plain water) and gender. The female participants recorded slower run times than the males, estimated at 45.162 (SEE = $\pm$ 16.940). However, the female participants ran faster when consuming the sports drink as opposed to plain water, identified by the term *water*, which is estimated as 6.859 (SEE = $\pm$ 2.239). Separate analyses were performed on emotion, with the terms *happiness* and *anxiety* included in the model (Table 11). The model identified a significant effect for these terms, with females feeling happier drinking water, estimated as 1.232 (SEE = $\pm$ 0.0401) and more anxious drinking the sports drink, estimated as -0.494 (SEE = $\pm$ 1.093). The interaction term, Treatment x week (drink type x weeks 1-6), for happiness 0.144 (SEE = $\pm$ 0.070) and anxiety -0.179 (SEE = $\pm$ -0.068) showed that these responses diverged by week.

Table 10

Multilevel Regression Analysis Predicting Running and Stroop Performance Times

Parameter	*Run*		*Stroop*	
	Estimate	SEE	Estimate	SEE
Fixed Explanatory Variables				
Constant (a)	186.219	± 11.438	23.994	± 2.104
Female (Δa)	45.162	± 16.940	2.789	± 3.104
Water (Δa)	6.859	± 2.239	0.338	± 0.436
Week	1.113	± 0.560	1.138	± 0.109
Rep	0.620	± 0.452	0.620	± 0.452
Random Variables				
	Variance			
Level 1 (within individuals)				
Constant (a_{ij})	292.296	± 25.394	12.028	± 1.017
Level 2 (between individuals)				
Constant (a_i)	477.252	± 262.878	15.897	± 8.810

Note. Values are means and standard errors of estimate (SEE). *Note.* Values are means and standard errors of estimate (SEE). Running and Stroop times were expressed in seconds. Male participants who consumed the sports drink (SPD) at week 1 and rep 1 were used as the baseline measure (a) and females, those who consumed water (WAT) were compared with it, indicated by (Δa), at subsequent weeks and reps.

Table 11

Multilevel Regression Analysis Exploring Within- and Between-Individual Variability in Happiness and Anxiety, and Treatment x Week Interactions

Parameter	Happiness		Anxiety	
	Estimate	SEE	Estimate	SEE
Fixed Explanatory Variables				
Constant (a)	2.921	± 0.341	2.885	± 0.744
Female (Δa)	1.232	± 0.0401	-0.494	± 1.093
Water (Δa)	0.007	± 0.294	0.642	± 0.288
Week	0.031	± 0.048	0.120	± 0.047
Rep	0.067	± 0.028	-0.119	± 0.027
Treatment x Week	0.144	± 0.070	-0.179	± 0.068
Random Variables	Variance			
Level 1 (within individuals)				
Constant (a_{ij})	0.225	± 0.144	1.084	± 0.091
Level 2 (between individuals)				
Constant (a_i)	1.206	± 0.102	1.993	± 1.088

Note. Values are means and standard errors of estimate. Happiness and Anxiety scores were rated nominally on a Likert Scale (1-7). Male participants who consumed the sports drink (SPD) at week 1 and rep 1 were used as the baseline measure (a) and females, those who consumed water (WAT) were compared with it, indicated by (Δa), at subsequent weeks and reps.

6.5 Discussion

This study examined the effect of consumption of a sports drink containing carbohydrate on both physical and cognitive self-control. There was evidence that consuming sports drink associated with faster running and Stroop task performance. Analyses revealed that there was a gender effect with females appearing to benefit more from the sports drink (See Table 10). In addition, when emotion was factored into the model as an explanatory variable, participants reported feeling happier when consuming the sports drink and more anxious when consuming plain water (See Table 11); an effect that diverged over the six weeks.

Although previous studies have questioned the role of glucose in self-control (Carter & McCullough, 2013; Kurzban, 2012), the present study appears to support emerging evidence that carbohydrate has a performance benefit that can be explained by non-energetic mechanisms (Molden et al., 2012; Sanders et al., 2012). Previous studies have not explicitly examined potential mediators of this effect. In this study, emotion was assessed as a possible mediator, in response to altering energy levels via a sports drink.

The present study also moved beyond the design employed in previous self-control training studies by asking all participants to undergo both treatment conditions. Although the sample size was small, an advantage of this approach was that the participants acted as their own controls, thus protecting against confounds that are associated with selection techniques for between-subject factors. In addition, the use of multilevel modelling allows for estimating the pattern of variation among individuals. Thereafter, it is possible to explain this pattern in terms of general characteristics by incorporating further variables into the model.

Several researchers have attempted to maintain self-control levels and minimise vulnerability to poor performance via novel strategies. For example, Job, Dweck, and Dalton (2010) showed that, by leading participants to believe that self-control resources are unlimited, it is possible to maintain subsequent performance. The authors reasoned that, by sensitizing people to cues about their availability of mental resources, it might be possible to also sensitize people to cues about fatigue and motivation. Thus a belief about unlimited resources might trigger the belief that one has capacity to sustain effort. Previous research has also found that manipulating motivation has a similar beneficial effect on performance. For example, Muraven et al. (Muraven & Slessareva, 2003; Tice, Baumeister, Shmueli, & Muraven, 2007) showed that the depleting effects of initial efforts at self-control are reversed by increasing incentives and positive affect.

Although the present study builds on existing knowledge about the role of carbohydrate in self-control processes, it is worth recognising the limitations with the present study. A first limitation concerns the measurement of self-control. Extensive practice on the Stroop task is likely to have led to faster inhibition through faster processing of the stimuli, rather than improved inhibitory control. In other words, over the course of the study it is possible the pattern of responding to the stimuli became automated. Second, the study did not include a measure of perceived palatability of the sports drink. Previous research has demonstrated that palatability has a significant effect on sports drink intake during recovery (Wilmore, Morton, Gilbey, & Wood, 1998). A useful avenue for future research might be to test the effects of sports drinks of different palatability or the effects of individual differences in palatability of sports drinks on the relationship between self-control and sports drink consumption. Heneghan et al. (2012) argue that athletes should develop their own carbohydrate intake strategy largely by trial and error. The findings from the present study extend this proposal. Third, participants were instructed to drink ad libitum. Previous research suggests that such instructions are an ineffective means of maximising performance as participants are likely to drink too late and not frequently enough. However, it is argued that athletes are more likely to drink ad libitum during training sessions than adhere to a prescribed frequency and volume strategy (Hagger & Montasem, 2009). Fourth, training intensity was not measured. Although heart rate was measured, heart rate drifts over time and lags behind over short-duration high-intensity exercise. To support the use of heart rate measurement, the inclusion of the session rating of perceived of exertion (sRPE; Foster et al., 2001) method would have provided a combined tool to evaluate the training intensity of the sessions, between conditions and weeks.

Recent research in sports science questions the validity and reliability of using a single piece of data as a measure of performance. Moreover, researchers are often criticised for making claims about laboratory studies assessing the impact of interventions to enhance performance, as they do not carry over to real world athletic settings (Walsh, 2014). Due to the problematic nature of field-based performance, such as environmental conditions, nearly all training studies are conducted in the laboratory. Consequently, researchers have not been able to report the effects of treatments in actual training. Thus, if interventions are to have a meaningful effect, they should be demonstrable across multiple performances. There is good reason to conduct multiple measures experiments: they allow researchers and practitioners to identify the normal variation in performance. Models of change can be estimated that do not presume that change is linear over time

Examining the effects of beliefs is very important when evaluating whether an intervention has worked. Individuals are conditioned to believe that a product works based on elite athlete endorsement or aggressive marketing campaigns by large sports product organizations. In their review of placebo effects in sport, Beedie and Foad (2009) suggest that potential mechanisms could be related to expectancy-driven changes. In the absence of suitable control data, it is impossible to be sure that any differences can be attributed to the intervention. However, if the athletes gain self-efficacy—and self-efficacy leads to increased effort—then performance could improve albeit via a different pathway. One possible explanation is that improvement stems from increased effort rather than metabolic changes associated with the intervention. Therefore, when following any intervention, it is important to ask why it works and what is the underlying theory that can explain changes?

In conclusion, the multilevel regression analyses have revealed consumption of a sports drink, gender and emotion as explanatory variables for improved running and Stroop task performance. However, further research is needed to examine the effect of sports drinks on perception of effort and emotion.

Chapter 7: General Discussion

7.1 Introduction

This general discussion will draw together the key findings from the programme of work, discuss the theoretical and applied implications of these findings, recommend how these suggestions would be tested in future studies, and conclude by addressing the research problem.

The research question was posed as: does willpower resemble a muscle? This thesis presents a series of experimental studies designed to test competing predictions about consecutive acts of self-control. According to the strength model, self-control operations are analogous to muscular fatigue. The model predicts that, just as a muscle's ability to generate force declines during vigorous exercise, self-control exertions lead to a progressive reduction in the capacity for further self-control, which has a detrimental effect on subsequent performance. Similarly, this process can be reversed with rest, and training should elicit better self-control outcomes. A challenge to this model is provided by Beedie and Lane (2012) who argue that the resource issue is one of allocation, and not supply. In proposing a role for emotion and motivation as the mechanistic explanation for how resources are allocated, they recommend that participants should be matched to experimental tasks, and that emotion should be tested as a potential mediator of self-control. Their criticism of previous self-control studies is that participants are often recruited to perform experimental tasks that have little or no meaning, or indeed require minimal physical exertion. Thus, the experimental approach allowed Beedie and Lane's recommendations and call for assessment of emotion in self-control experiments to be integrated into work.

Four studies followed previously established methods, i.e., participants performed two ostensibly dissimilar self-control tasks in succession. Two additional experimental studies applied these ideas to field-based sport psychology interventions. An important extension of this previous work was to use tasks that more closely resemble normal athletic competition. That being, the approach was to use time trials and skill-based assessments of performance as these have greater validity and reliability than time-to-exhaustion protocols. As such, it was hypothesised that (sports) participants would want to perform well in these tasks.

7.2 Summary of the Main Findings

The main findings can be summarised as follows. In Study 1, Experiment 1, participants demonstrated a pattern of regulatory depletion consistent with previously reported findings. In two conditions, participants either performed an incongruent (self-control depletion) or congruent (control) Stroop task before and after performing a virtual reality cycling task, on an indoor cycling ergometer. Mean performance times suggest an effect for prior self-control exertion but this result was not significant. Stroop task performance was however significantly worse before and after, for the depletion condition. However, the findings from Experiment 2 painted a somewhat different picture. Performance was not impaired on the proposed meaningful task (cycling) and Stroop task performance improved across the three trials. In addition, participants reported feeling happier and more motivated to perform well on the second cycling task.

Study 2 showed that completion of a soccer-passing task requiring self-control led to worse performance on the wall squat endurance test. The findings suggest that prior self-control may lead to participants withdrawing from engaging in self-regulation on subsequent tasks. The findings showed that higher anxiety associated with exerting self-control during the soccer task; a factor that may explain wall squat performance. Further investigation of the mechanisms explaining performance on novel self-control tasks is warranted.

It may be possible to manipulate depletion effects by short (Study 3) and long-term (Study 4) interventions. Study 3 showed that the use of a pacemaker, to improve 1600 m track running performance via reducing the amount of self-regulation effort required, did not affect overall time but did influence pacing strategy. Participants ran a faster first lap when following a pacemaker, but reported feeling more anxious, suggesting that interventions designed to enhance performance have important implications for emotion, which may counter the proposed performance benefits.

Study 4 examined the effectiveness of sports drink consumption on performance in a series of cognitive (incongruent Stroop) and physical (high-intensity track running) tasks. Results showed that sports drink consumption associated with faster running and Stroop task performance. Moreover, participants reported feeling happier. In contrast, participants felt more anxious when consuming just plain water.

Finally, as an adjunct to the empirical work presented in the main body of this thesis two further studies were undertaken as part of the PhD experience. These examined the applied implications for self-control interventions. Study 5 (appendix I) examined emotion regulation strategies designed to enhance 1600 m running performance. Results indicated that that running time did not improve or worsen. The intervention designed to increase unpleasant emotions led to higher anxiety and lower calmness. The intervention designed to decrease unpleasant emotions was associated with a slower first 400 m, lower anxiety and calmness. Study 6 (see Appendix J) examined the potential paradoxical effects of delivering psychological skills interventions, using the strength model as a theoretical framework. Results showed both imagery and control groups improved swimming tumble-turn performance, a finding that is counter to the strength model which predicts that sequentially performed self-control tasks should lead to worse performance. Similarly, the finding that the imagery group did not show greater improvement goes against the purported added benefit of motor imagery training.

7.3 Theoretical Implications

This next section discusses the broader theoretical implications of these findings.

7.3.1 Ego Depletion Effect

A decline in performance across self-control tasks is commonly reported as evidence of ego depletion. The most popular explanation for this is the glucose hypothesis (Gailliot et al., 2007). However, the findings from this thesis show limited support for the ego depletion effect and thus point to alternative explanations. One explanation for the convergent findings is that the experimental procedures serve to bias participants. In recent years [since the present work began] there has been increased interest in the ego depletion effect and focus on the scientific rigour of Gailliot et al's experimental studies. Given that self-control fallibility affects individuals and society, ego depletion findings have enormous implications. If glucose is central to self-control operations—and replenishment restores self-control—then the message is somewhat of a catch-22 for individuals for whom self-control is their undoing. The idea that dieters must consume energy-dense food, such as chocolate, in order to resist it [chocolate] makes no sense at all.

Francis (2012) argued that when a set of experiments has too many successful replications, scientists should be suspicious that null or negative findings have been suppressed the experiments were run improperly, or the results were analysed improperly. Although an accumulating literature (at the time of this writing) suggests there is little or no evidence to support the link between glucose and self-control (Carter, Kofler, Forster, & McCullough, 2015; Lange & Eggert, 2014; Lange et al., 2014; Schimmack, 2012; Vadillo, Gold, & Osman, 2016), such findings overlook the multitude of studies that have successfully replicated the basic pattern of behaviour on sequential tasks. Researchers therefore should continue to investigate why and how this happens.

From a theoretical perspective, capacity theories assume that the patterning of human performance cannot be fully understood without reference to a concept of resources. These are conceptualised as the availability of one or more pools of general-purpose processing units, capable of performing elementary operations across a range of tasks, and drawing upon common “energy” sources (Gopher, 1986; Kahneman, 1973; Wickens, 1984). There may be several such resource pools, as in multiple resource theory (Navon & Gopher, 1979; Wickens, 1984), serving different families of processing needs. Recent developments to the strength model uphold the notion that resources (psychological and/or physiological) are depleted, even if they are not truly depleted in the strictest sense (i.e., reduction in blood glucose) (Vohs, Baumeister, & Schmeichel, 2012). The [limited] resource construct does imply scarcity, if simultaneous mental operations must compete for allocation of the same resource. However, until this resource is identified (if it can be), and the metabolic cost associated with its usage quantified, the term *depletion* is somewhat of a misnomer. Depletion of physiological substrates is altogether different to that of a decline in work or performance on tasks, and the effort one is prepared to invest in maintaining self-control. As such, researchers would be well-advised to avoid misuse of scientific terms and nomenclature, and be more prudent in their use of terminology (Edwards et al., 2016).

In contrast, from a behaviourist's perspective, rather than look at self-control tasks in isolation, the pattern of behaviour should be viewed in the context of other tasks. The findings from Studies 1 and 2 suggest that performance on a novel task does not provide participants with enough information about the self-control nature of the task. First, difficulties can occur when the person does not have appropriate standards against which to compare the current state/ performance (i.e., a previous pattern of behaviour). Thus, when participants are perhaps unaware of the need for self-control, impaired performance following prior self-control exertion may reflect methodological issues rather than conceptual ones. Second, performance may be compromised when the participant does not monitor the discrepancy between the current and desired performance, and does not consider the discrepancy as requiring action. As Study 1 (Experiment 1) showed, novel tasks presented to participants for whom the resources required for sequential-tasks is unknown is not necessarily indicative of self-control failure, rather an inability or lack of motivation to recognise the demands of the task, or mobilise resources. This suggests that the sorts of cognitive resources loaded by traditional executive tasks as such do not overlap, in the cognitive architecture, with the emotion-based learning skills

Third, novel tasks may be just that and the mechanisms explaining self-control processes differ to those required for familiar tasks. As Study 1 highlighted, simply familiarising oneself with the task could lead to improved performance. When a task is presented for the first time, and incongruent with the individual's personal priorities, it is unlikely the individual will be able to allocate sufficient resources to meet the demands, for the processes by which resources are mobilised are unlikely to be established. At present, the explanation for commonly seen laboratory-based ego depletion effect appears not be a limited energy supply but a lack of motivation or clarity about the goal.

This thesis provides some empirical support for the assumption that the decrease in self-control strength is presumably not permanent. Where experimental tasks are contextualised as either relevant or meaningful, then participants are unlikely to perform worse across successive attempts. The sequential task paradigm employed in Study 1 showed that initial self-control exertion can lead to performance benefits, at least when future tasks require minimal self-control. The mobilisation of resources for initial self-control may exceed the amount that is actually needed so that, when future tasks are performed and anticipated as demanding but are less so, individuals have more than sufficient resources to maintain performance. Hence, it is also likely to be perceived to be easier.

To conclude this section, the account offered by Gailliot et al (2007) is to be commended for its contribution to the field. Following on from their glucose hypothesis, the bank of literature examining the effects of self-control on performance has grown tremendously. Not only have researchers tried to replicate their findings, their work has attracted interest from a multitude of fields including cognitive neuroscience, sport and exercise science and behavioural economics. Understanding what neural substrates underlie self-control is just one component of self-control theory. One must also consider how these resources are mobilised to support self-control attempts. Thus, it is important that researchers do not neglect the importance of both approaches if they are to provide a unified theoretical framework.

7.3.2 Resource Allocation

According to the strength model, if performance can be maintained or improved, then a potential mediator must have the ability to circumvent the effects. That is, following task 1, the mediator must be able to explain the performance effect on task 2. Although McEwan et al. (2013) argue that research has generally failed to address this issue, Beedie and Lane (2012) outlined a potential role for emotion and motivation in the process. Using this idea, the present work found emotion to associate with [experimental] condition across all studies.

Emotion was hypothesised to regulate and motivate action for self-control. In particular, motivation to do well on the task was considered to be an important factor determining the intensity of the emotional response. Central to Beedie and Lane's (2012) conceptualisation, the mobilisation of resources for performance depends on the urgent need for self-control. This demand will be met via allocating resources towards self-control attempts. However, the implication is that, from this perspective, some mental and behavioural processes are more expensive than others.

It is surprising that increases in emotion were not accompanied with increases in heart rate, or ratings of perceived effort. However, given the duration of the tasks that involved heart rate measurement then this finding is not altogether surprising.

Therefore, the act of asking people to state explicitly a goal provides a criterion for measuring whether self-control has been achieved. If no goal is set, then there is no way a researcher is able to interpret that behaviour is the result of self-control failure. Asking a participant to state a goal allows people to implicitly consider the task's meaning with reference to possible outcomes across time, providing some indication of the motivational urge to behave in a certain manner to achieve the goal and the restraint (if any) opposing it (Inzlicht & Schmeichel, 2012).

The line of reasoning addressed above suggests that positive affect can implicitly motivate people to control their goal-directed behaviour in a more flexible or rigid way. If people represent their behaviour in terms of the goal guiding their actions, then positive affect motivates people to control their behaviour at the goal level. This enhanced goal motivation should render goal-directed behaviour more flexible, as people are keen to switch attention to other means in order to reach the goal if the previous means is no longer valid.

In summary, more than one resource is likely to be able to support self-control processes. The account does not necessarily challenge the strength model, but provides a more detailed account of why self-control failure is not inevitable and how one changes his/her actions. Reallocation would suggest the resources exist but, in the case of pacing, one cannot judiciously decide to fuel effort in other ways if those systems cannot support the action. Thus, the decision to withdraw effort may ultimately be a conscious one, but it is most certainly driven by internal mechanisms (i.e., peripheral signals).

7.3.3 Motivation

The findings from Experiment 1 (Study 1) and Study 2 are consistent with the strength model predictions. However, the experimental procedures meant that the experimental tasks could not be viewed in a wider context. Thus, providing additional iterations of the experimental tasks in the subsequent studies showcased how each individual act of self-control is embedded within a pattern of behaviour. For example, Experiment 2 (Study 1) showed that when participants performed further attempts they recorded faster completion times. The format of the cycling tasks required participants to race virtual competitors. Thus it is conceivable that the increase in motivation and happiness across the two trials can be aligned with the demands of the task (i.e., to finish first).

To explore the above point further, Study 2 used an open-ended second task. The wall squat enabled more flexibility to exert self-control and examine how participants behave when they are asked to persist on a task. Participants were instructed to complete a task as *fast* as possible, whereas they were instructed to perform the wall squat for as *long* as possible with effort being entirely volitional. An alternative explanation by Inzlicht and Schmeichel (2012) is that participants shift their attention and motivation from task 1 to task 2. Thus, once they had performed the task they believed they were being assessed on (footballers performing a soccer task), they may have thought they had done what they had been asked to and the rest was up to them. However, the strength model predicts that if performance suffers on task 2, then the participant was trying to self-control in the first task. A second iteration of the first task, for both groups, would have indicated whether participants were more motivated to perform the soccer task—or indeed had shifted their attention to the second task—as too would asking them to rate which task is more important.

However, this account may overlook the fact that participants are naturally inclined to rest following self-control exertion, and subsequent performance is evidence of that. Participants consistently rated the tasks as important, a finding consistent with others (Boucher & Kofos, 2012; Xiao, Dang, Mao, & Liljedahl, 2014). The way people represent their behaviour (in terms of goals or means) thus seems to rely on the context at hand.

7.2.4 Manipulating Self-Control Strength

Multiple lines of work have identified interventional methods that can induce or reverse proposed ego depletion effects. Ego depletion has been induced using performance feedback to manipulate emotion (Beedie et al., 2012), asking participants to make choices. Offering participants incentives (Muraven & Slessareva, 2003), inducing positive affect, glucose rinsing, and forming implementation intentions appear to be effective methods to regain self-control. However, there has been little attempt to replicate some of the performance enhancing strategies used by athletes. Study 3 sought to attenuate self-regulation, and thereby improve 1600 m track running performance, by employing a pacemaker. Specifically, the employment of a pacemaker was hypothesised to alter behaviour related to goal setting, namely self-regulation effort (pacing). Goals are proposed to steer relevant information towards enacting behaviour that should support successful attainment of the goal, as well as controlling attention (Aarts, 2012). The findings from Study 3 suggest that the presence of another runner (pacemaker) may influence the behaviour of a runner through influencing decision-making (i.e., pacing strategy). Specifically, following a pacemaker appears to promote a rigid course of action whereby runners are less inclined to deviate away from the intended pacing strategy. In contrast, self-pacing appears to promote greater flexibility whereby runners are more likely to pursue alternative means to reach their goal. The inability to enact a desired pacing strategy and the employment of a strategy consistent to that previously reported in the literature suggest that athletes develop stable pacing templates when self-regulating. However, when performing novel tasks, albeit designed to improve performance, athletes must practice self-regulation. The subsequent studies focused on the effects of practicing self-regulation on performance.

7.3.4 Self-Control Training

Providing sufficient rest and recovery is scheduled between tasks, then practicing self-control should result in an improvement in self-control ability (Muraven & Baumeister, 2000; Muraven, Baumeister, & Tice, 1999). Applying the muscle analogy, when participants are clear about the need to self-control, or appraise the task as important, performing sequential self-control tasks could act as a warm-up prior to further self-control tasks.

The finding from Study 3—that the self-paced group followed a more even-pacing strategy than the paced group—suggests that well-trained runners may already have sufficient capacity to self-regulate. The findings would support the notion that repeated practice is likely to be beneficial. Whether practicing self-control has far-transfer effects requires further investigation. Moreover, longer-term studies are required to examine whether the effects disappear. Study 6, however, provides an interesting implication for self-control training. That is, practicing self-control could impair performance.

7.4 Limitations

Within the present body of work, there were a number of limitations that should be considered. The experimental procedures followed those used in previous studies. An important factor when designing any performance protocol is that measurement of performance can detect the smallest meaningful effect.

Specifically, a notable limitation of previous ego depletion protocols is that many of the proxy measures for resource depletion do not represent true meaningful performance outcomes: i.e., the measure (i.e., number of errors, time spent on task) does not represent a goal or standard for which the participant is trying to attain but one that is imposed on the participant, or the participant is not aware of. Although the use of performance protocols such as time trials was a feature of the present work, and used to address such issues, time-to-exhaustion trials may in fact be a better assessment protocol for testing the conservation (Muraven & Slessareva, 2003), or allocation, of resources (Beedie & Lane, 2012) hypotheses. There are arguments for and against their use. The reliability of measures is important for assessing change between repeated measurements.

A lack of motivation alongside boredom in constant-power tests with no defined end point (Schabort et al. 1999) may contribute to a poor reproducibility of such tests, particularly when each subject is required to repeat them a number of times. The repeatability of tests might be improved by providing feedback with regard to performance during the bouts (Schabort et al. 1999). For instance, Pageaux, Lepers, Dietz, and Marcora (2014) recently that showed that Stroop task completion impaired subsequent 5km running performance. It would be worth exploring whether repeated visits continues to demonstrate this effect, or whether participants simply conserve effort for the sports task, which should be the case if they prioritised their efforts. If participants could freely choose how much time to spend actively engaging in self-control, with the knowledge that what they are about to be asked to do is likely to compromise subsequent performance, then it may be that they withdraw from the first task.

Sample size. Collectively, the findings from this thesis failed to replicate previously reported moderate-to-large effect sizes in empirical tests of the ego depletion effect (i.e., significant performance deterioration). For each experimental study, participants were randomly allocated to either a depletion or control group, with the exception of Study 4 which used a within-subjects design. This approach was consistent with previous studies as it allows performance in self-control tasks to be compared to performance on non-self-control tasks. The findings are, however, limited by small sample sizes, which in part may reflect inflated effect sizes previously reported for the ego depletion effect. To overcome some of the problems with the small sample size recruited for Study 4, a repeated-measures within-subjects design was administered whereby participants acted as their own controls. In sport, this design has considerable utility as it eliminates comparison of group means and accounts for individual variation associated with performance. Furthermore, in the context of sports performance, longitudinal data has arguably greater external validity for practitioners – that is performance is more likely to reflect real world findings. An acknowledged limitation is the small sample sizes used in this thesis.

Task characteristics. One potential oversight of the experimental tasks was the instruction given to participants. For example, the Stroop task was presented to participants following instructions used in previous studies. However, these instructions did not instil habits (i.e., entrain normal responses to visual stimuli) and thus participants did not have to override any conflict. As the Stroop task was simply presented to participants, it is entirely plausible that participants just followed the instructions to read the shapes rather than correct the description presented below (Cohen, Dunbar, & McClelland, 1989). Once they were familiarised with the task then self-control demands become negligible. To overcome this limitation, participants should first practice the task without self-control needed before completing the task which requires self-control. This way the participant has to override this habit. An example of this in real life could be overriding habituated motor skills with new skills in order to enhance performance, as shown in Study 6.

Building from the above point, then the need to establish normal patterns of behaviour ahead of experimental protocols becomes salient. Study 1 (Experiment 2) suggests that physically active individuals may habitually exert extra effort to better previous performances on tasks. After all, the dependent measure, cycling performance, is a relevant and meaningful task for this population. Similarly, Study 3 found that athletes run to certain a pacing strategy even though they know it might not be optimal for performance; and the findings from Study 4 suggest that athletes are likely to persist at self-regulation (strive to improve training performance) as training is seen as worthwhile endeavour. These studies all share a commonality, to pursue behaviour that is perceived to be more beneficial than the current or past behaviour. Further drawbacks of the Stroop task include its validity as a self-control measure. It may be better suited to measuring attention as the resources required for ignoring distracting stimuli draw on different resource pathways to those used for self-control. Successive practice of the Stroop task primes connections between stimuli so that accurate responses become easier and speed up the processing.

Selecting a meaningful independent self-control task for a population may appear straightforward: it offers researchers the chance to be creative and blind participants from the self-control demands. However, identifying an ostensibly unrelated self-control task for the dependent task is more problematic. Tasks such as the Stroop has properties that require fast, automated processing, whereas the wall squat could be regarded as having the opposite. This could explain why the Stroop task is less vulnerable to ego depletion. Self-control tests vary widely. To date, researchers have measured self-control using tasks with poor external validity. The argument that handgrip strength or Stroop task performance is a valid measure of self-control ability is weakened when there is no evidence that participants completed baseline assessments. The absence of baseline data in this thesis is an acknowledged limitation and introduces the risk that any differences in outcome are the result of pre-existing individual differences in physical and/ or mental capacity. For example, baseline data for participants in Study 3 could have been used to help participants identify a real-time goal. Furthermore, physiological afferents of performance could have identified the exact intensities participants were exercising at—although the results for this type of methodology have been mixed. For example, Pageaux, Marcora, Rozand, and Lepers (2015) found that although heart rate differed between groups on the self-regulation task, this effect disappeared on subsequent whole-body endurance exercise. Importantly, the authors found that perception of effort was higher among the mentally fatigued group.

One perspective is that self-control may be trait-like. Thus some researchers have assessed whether it interacts with situational demands; that is, are participants who self-report as low in trait self-control more susceptible to ego depletion? However, although these measures are reported to be valid, evidence of this is weak—or should at least be questioned—before suggesting they are reliable and sensitive to situational demands (discussed in Chapter 2). For this reason, these measures were not included in the present work but would be worth exploring in the future. If researchers can demonstrate that these measures *do* assess trait-like characteristics, then they offer a potential correlate to help identify vulnerability to self-control failure. One recommendation to enhance this line of enquiry would be to make use of technology to track self-control behaviour in real-world settings, with the goal of producing individualised patterns of behaviour that can become the target of intervention work.

Experimental protocols. Another limitation was that participants did not complete sufficient familiarisation trials. The mixed results from Study 1 suggest that performance on novel self-control tasks may be due to practice effects. Specifically, familiarisation with the demands of the task may have accounted for the results. The reversal of findings in Experiment 2 would support this conclusion. However, given that self-control is proposed to operate automatically, many studies have used novel tasks whereby participants are presented with tasks without any previous experience. Still, future studies should ensure that experimental protocols are assessed for reliability and validity prior to their use. One possible explanation, already suggested in the literature, might be that completing a self-regulatory task causes participants to think they have fulfilled their experimental obligation and so they disengage from any subsequent tasks.

The traditional approach to ego depletion effects has been the use of the dual-task design. This method involves manipulating an independent variable, such as asking participants to deploy attention towards a specific cue, and then measuring the effect on a dependent variable, such as time to completion on a cognitively or physically challenging task. If performance degrades when participants must perform a second task, then the primary task requires control. Although this protocol allows researchers to establish cause-and-effect relationships, and points to the mechanisms that caused the act, this approach may hide the behaviour, or discrepancy, participants are trying to control.

7.5 Strengths of the Present Research and Contribution to Literature

The strengths of this research programme are summarised as follows. A particular contribution of the present work was to extend previous calls to examine mediators of self-control. If the psychophysiological processes explaining self-control performance are to be elicited, then researchers must begin to identify, and test, possible mediators. Beedie and Lane (2012) proposed that emotion mobilises energy for self-control. This thesis integrated measures of discrete emotions and used protocols that encouraged participants to better performance. Changes in specific discrete emotions (Study 1, happiness; Study 2, anxiety; Study 3, anxiety; Study 4, happiness and anxiety; Study 5, anxiety and calmness) were reported between conditions suggesting that emotion may have an important role in self-control. On this evidence, it seems equitable to suggest that gaining a better understanding on the precise function of certain discrete emotions might benefit self-control and sports performance.

In addressing the recommendations of Beedie and Lane (2012), rationally selecting participants to perform experimental tasks hypothesised to be contextually relevant and meaningful served to maximise ecological validity. Baumeister et al. (2007) used an endurance performance task as a self-control task, arguing it requires overriding the sensation to stop in order to continue working towards some standard (e.g., goal time). To illustrate this point, the running tasks were chosen as they simulated trials that participants had experience of. Runners are habituated to running on tracks with performance times being measured. Thus, the performance could be compared to normal training and performance, beyond that which just served an experiment. The degree to which any selected task is meaningful to any one individual will vary substantially, even within apparently homogeneous groups. Including this in the proposed research represents another important extension of past work.

Beedie and Lane (2012) proposed that where tasks are not meaningful to an individual, they will require less (or no) self-control, and consequently may not result in ego depletion. With this in mind they emphasised the need for this in their paper, and highlighted it as an obvious gap in the extant literature. The lack of meaningful tasks is surprising as researchers typically argue that further studies are needed to help develop interventions designed to enhance self-control. If research is to lead to interventions, then the tasks used in a study should be ecologically valid. Beedie and Lane argued that researchers should determine the extent to which various self-control tasks are meaningful to people ahead of conducting experiments, either via empirical means such as pilot work, or by selecting participants hypothetically matched to tasks (e.g., a dietary task used with people who may be susceptible to lapses in self-control with food intake, such as overweight dieters).

On this basis, over and above the strategic selection of hypothetically matched tasks and participants described above, post-hoc quantitative and qualitative assessment of the degree to which participants perceived the task as meaningful should be conducted. The mechanisms of self-control are more likely to be elucidated if researchers have data indicating the perceived meaningfulness of a task and if they are able to ascertain from participants, in those participants' own words, why they believe they did or did not achieve self-control in relation to the task(s) performed. Including this should be an important part of any theory-led intervention.

Finally, the present work extends the limited amount of research on self-control in naturalistic settings. The reason for conducting work in this context is that social cues and personal objectives activate self-regulatory behaviour in ways that the laboratory settings cannot. A key aspect of the research approach was to focus on overt behaviour, rather than focus too heavily on introspection or physiological mechanisms. For example, each study was framed such that context-specific effects on self-control could be assessed. Study 3 measured performance intentions and then actual performance and pacing strategy to gain insight into how runners self-regulate when running alone or with a pacemaker. The use of experimental protocols in the field allowed for data to be captured in the real-world and strengthen the generalizability of the findings. Mitchell (2012) urged caution against claiming practical significance when laboratory findings may turn out to be misleading about the nature of relations among variables outside laboratory settings. In his meta-analysis, he reported that effects found in social psychology laboratories most frequently changed signs in the field (from positive to negative or vice versa). Replication of the presented experiment using behavioural measures would be feasible

7.6 Applied Implications

The findings from this thesis have applied self-control theory to understand sports performance. The decision for an athlete to undertake self-control tasks should consider both the short-term and long-term effects associated with self-control exertion.

The field-based experiments demonstrate examples of how individuals can use protocols often confined to laboratory settings to develop systematic strategies to improve self-regulation, or measure performance, as part of their own training. Specifically, the finding of Study 6 (Appendix F) can inform applied sport and psychology practice by showing that practitioners should view the implications of intervention work from a self-control perspective. Taking on too many self-control tasks (i.e., introducing new training stimuli), performed sequentially, may lead to short-term overload of self-control resources resulting in self-regulatory failure and thus compromised performance.

Hagger et al. (2010) used the strength model hypotheses as a theoretical model to explain poor exercise adherence. The authors proposed that when individuals embark on a new exercise regime, they must consider recent self-control demands. If they anticipate future demand to be great (e.g., more barriers to overcome), then they are likely to conserve resources. Therefore, if a person decides to initiate several health-related behaviours that require self-control simultaneously, he/she is likely to be vulnerable to ego depletion as he/she will have an excessive demand on self-control resources and may fail to persist in regulating some of all of the demanding behaviours. However, if he/she staggers the initiation of these behaviours by introducing them progressively one at a time then there are less likely to be such excessive demands of self-control resources. This is because he/she may "build up" self-control strength through the training of his/her self-control capacity by the first-introduced behaviours. This increased strength may provide the additional resources to successfully regulate behaviour when additional health-related behaviours are introduced (Hagger et al., 2010).

As Study 1 highlighted, simply familiarising oneself with the task could lead to improved performance. When a task is presented for the first time, and incongruent with the individual's personal priorities, it is unlikely the individual will be able to allocate sufficient resources to meet the demands. The explanation for this appears not to be a limited energy supply but rather a lack of motivation or clarity about the goal. Thus, establishing expectations prior to intervention work is a must for any practitioner.

A relevant model for training self-control could be borrowed from endurance athletes. Chapter 2 discussed that, in the same way endurance athletes modify aspects of their training to produce training-induced adaptations that enhance performance, people wishing to improve their self-control could target parameters malleable via psychological means. For example, elite-level athletes already have a large capacity for consuming oxygen. Thus, to make running feel easier, these athletes might target training interventions that promote running efficiency. By becoming more efficient at utilising oxygen and alternative metabolic substrates they consume less oxygen for a greater workload at a given intensity (Jones, 2006). Applying this to individuals with low self-control strength (i.e., capacity), a viable method to achieve better self-control could be to improve self-control *efficiency*. That is, they should seek strategies whereby they expend less effort on maintaining self-control for the same given *load* (i.e., level of depletion). In practice this could be achieved by: altering expectations prior to engaging in self-control tasks (Job, Dweck, & Walton, 2013); learning habits that are desirable and can be entrained to occur automatically (Alberts, Martiijn, Greb, Merckelbach, & de Vries 2007); and challenging beliefs about fatigue (Noakes, 2012).

If the psychophysiological processes explaining self-control performance are to be elicited, then researchers must begin to identify, and test, possible mediators. Beedie and Lane have suggested emotion and motivation as well as how one might go about testing such proposals. Furthermore, the law of diminishing returns could refine the explanation for performance deterioration. To put it another way, if there is not an overload or need to self-control, then the capacity to self-control will reduce. Thus, practicing self-control regularly is beneficial as it creates an overflow of resources which could improve performance.

7.7 Recommendations for Future Research

In many ways, the original assumptions outlined in the strength model have been applied beyond what the authors had probably intended. The assumptions provided the basis for several hypotheses that have been tested in diverse domains, and it was inevitable, given the muscle analogy, that it should attract attention in the sport and exercise psychology domain.

The failure to obtain evidence in support of the model and ego depletion hypothesis should see progress in theory development. Carter and McCullough (2014) questioned the robustness of the depletion effect and effect sizes previously reported by Hagger et al. (2010). The authors applied methods for estimating and correcting for small-study effects to the data from this previous meta-analysis effort, concluding they found very strong signals of publication bias, along with an indication that the depletion effect is actually no different from zero. The authors concluded that, until greater certainty about the size of the depletion effect can be established, circumspection about the existence of this phenomenon is warranted and that, rather than elaborating on the model, research efforts should focus on establishing whether the basic effect exists. However, that is not to say the strength model predictions must be discarded, rather they require further empirical work. Consequently, it may be time to question whether the traditional methodology used in experimental and social psychology to examine relationships between variables is appropriate for testing self-control theory.

And given the conceptual overlap between mental and muscular fatigue, there is no reason why researchers cannot develop an integrated theoretical framework. Thus, this next section will sketch promising research directions, based on the empirical work conducted for this PhD, for future research in this field. Specifically, the recommendations focus on populations to study and how to calculate and measure self-control behaviour.

The first recommendation for future research would be to examine differences between extreme populations; for example, novice versus elite athletes, underweight versus overweight, or young versus old. Learning from those who are successful at self-control will further unpack the mechanisms and the strategies they use. The research should be conducted on different and more diverse samples of users. Much of the focus has been on applying the strength model to self-control failure; for example, failing to adhere to an exercise programme or maintain emotional control and quitting on tasks designed to test volition. It is obvious that the processes that interfere with one's ability to self-control should be broken down to help individuals better their self-control. But equally, it is strange that there are fewer investigations of the processes underlying good self-control.

The second recommendation for future research is to focus on the measurement of self-control. If the strength model is to explain self-control failure, then the quality of ego depletion assessment tools needs to be improved. To date, self-control has been measured in the laboratory using a combination of subjective (e.g., rating scales), performance (e.g., reaction time, accuracy and number of errors) and psychophysiological measures (e.g., blood glucose, Gailliot et al., 2007; blood pressure, Wright et al., 2003, 2007, 2008; heart rate variability, Segerstrom & Nes, 2007; electromyography, Bray et al., 2008; electroencephalographic activity, Inzlicht & Gutsell, 2007). These methods have been unable to yield data that is sensitive enough to detect the varying self-control demands and thus explain the underlying psychological and physiological processes. As an example, the tasks are considered for their hypothesised difficulty (i.e., how demanding are they) and then participants self-report how hard it was to engage in self-control, how tired they feel and how willing they are to engage in further self-control. Yet, it is still not clear how best to calculate the level of self-control depletion, or make accurate predictions about how one is likely to perform before or after a self-control task.

Trait self-control measures have been used to identify those low in self-control (e.g., Tangney et al., 2004), but these measures do not provide indices of good, or poor, self-control, meaning that participants are not able to use this information to make improvements. Furthermore, the stability of these measures has not been reported (see Chapter 2; Fullerton, Lane, Nevill, & Devonport, 2016). A valid self-report measure would represent a useful and practical method researchers and practitioners wishing to identify those individuals who might be susceptible to poor self-control, as well as drawing attention to actions and behaviours that require self-control. Moreover, assessment of trait self-control would be particularly useful in predicting behaviour related to explicit behavioural intentions, as well as informing intervention design and evaluation.

Third, research should measure behaviour when participants' resources are *actually* depleted: i.e., to the extent they are not fully able to bring their behaviour into line with external norms. The tendencies and motives are more likely to be illuminated when people have just engaged in self-control and self-report as fatigued. At present, depletion is simply inferred by a decline in performance, which does not provide specific information on how demanding the task was (i.e., amount of resources used), the time spent actually self-regulating on the previous task, nor the effort expended engaging in self-control. It merely describes the pattern of behaviour. Thus ego depletion effects vary.

For one individual the effort component could consist of an immediate withdrawal as the task is too demanding or not perceived as important, or requiring large amounts of self-control. And so the individual's ego depletion score is heavily weighted towards the task (e.g., a novel task). Whereas for another individual the ego depletion score might be weighted by the performance, such as the time spent to complete the task. Again this individual may spend a lot of time on the task, not engaging in self-control, but because he/she has decided not to invest much effort. Calculating ego depletion using these components will bring together the strength model and resource allocation model, and help determine a suitable recovery spell relative to the self-control demands. Furthermore, it could help develop a method to predict self-control outcomes.

However, given that resources are just one component, then it could be argued that the term *depletion* is itself misleading if it is the large amount of effort invested in the task that is more indicative of the inability to maintain performance. Perhaps self-control researchers could explore some of the methods sports scientists are using to quantify training, not least some of the challenges they face when it comes to providing an arbitrary unit to encapsulate how much self-control was exerted (and thus remains).

Advances in other fields are likely to offer new insight into self-control. For example, the emerging field of neuroergonomics (Mehta & Parasuraman, 2013) involves developing the capability to continuously monitor an individual's level of fatigue, attention, task engagement, and mental workload in operational environments (i.e., natural work settings) using traditional behavioural and subjective measures alongside cerebral responses to understand the neural and physiological cost of work. No one method is likely to yield information about the state of an individual’s self-control capabilities but this approach marks a significant shift towards capturing behavioural data in naturalistic settings, while participants are physically active, and not confined to the laboratory.

Although interventions designed to modify bottom-up processes, such as habits (e.g., forming an implementation intention), have shown promising results, it may be that these strategies are more effective for those high in self-control, and thus more likely to benefit from strengthening automatic behaviour. Conversely, effortful top-down cognitive processes involving challenging beliefs, or asking why it is/not important to achieve a certain goal, may be more appropriate for those wishing to override unwanted behaviour. This approach would focus on reinforcing one’s motivation to pursue a chosen goal. This would certainly be a worthwhile avenue to explore for future research. It is likely that adopting a more tailored approach to assessing self-control in the laboratory facilitates intervention-based work. This type of work would work would best with participants acting as their own controls, rather than comparing group behaviour, and will most certainly provide more robust findings.

To conclude this section, there appears to be disconnect between rigorous application and understanding of the theory by practitioners, and an absence of clear guidelines from theorists as to how self-control theory translates into practice. There needs to therefore be a greater interplay between theorists and practitioners, in which theory is not only applied and tested rigorously but also refined based on the findings offered by those tests. Whilst researchers have favoured conducting laboratory-based studies, there is a case for conducting research outside in the field. Under laboratory conditions, participants often feel compelled to behave in a certain way, without freedom to self-select goals. However, outside of the laboratory then goals or standards are readily activated. In sport, it is likely to be a performance standard one seeks to attain, and so participants are provided with a standard to compare previous performances against. The freedom with which researchers could then explore the overt behaviour displayed during sport will surely facilitate the translation of experimental findings to practice.

7.8 Concluding Remarks

The present programme of research examined self-control in sport, specifically the strength model. To test this conceptual model, four experimental studies formed the core of this thesis, and tested the broad hypothesis that performance deteriorates across self-control tasks. Results failed to show unequivocal support for this hypothesis. Importantly, previously reported laboratory-based effects and those reported in the early stages of this programme of work did not transfer to the field. Thus, the current strength model may not offer a mechanistic explanation for performance. Emotion was associated with experimental condition, suggesting that it is an important factor which may explain self-regulatory behaviour. In addition, Studies 3 and 4 offered a new and interesting approach to the study of self-control, and should pave the way for future researchers to adopt similar performance protocols that simulate those used in sports competitions. A greater understanding of the role emotions play and their relationship with cognitive, physiological, and behavioural responses is warranted. Two further experimental studies supplemented this body of work, and investigated the effectiveness of sport psychology interventions. These studies have important implications for practitioners. Study 5 highlights the utility of self-help interventions for performance whilst Study 6 raises questions about the effectiveness of sports psychology interventions. Collectively, these findings challenge the empirical findings of the strength model.

This thesis adds to the extant literature by examining the effects of self-control on sports performance using a range of laboratory-based and field-based tasks. The information provides new insights into the mechanisms underpinning self-regulation, by showing that emotion has an important role between self-control and sports performance. Specifically, positive emotions—in particular, happiness—associated with better performance. Conversely, anxiety associated with poorer performance, consistent with the notion that high-activation unpleasant emotions might be costly in terms of resources. Future research might therefore profitably manipulate these emotion states to further understand self-control processes.

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Appendix A: Information Sheets, Informed Consent Forms and Debrief Sheets

A1. Study 1 Participant Information Sheet and Consent Form

UNIVERSITY OF WOLVERHAMPTON

Participation Information and Informed Consent

Primary Researcher: Christopher Fullerton

Supervising Researchers: Professor Andy Lane and Dr Tracey Devonport

Project Title: Emotions and Performance

You are being invited to take part in a research study. Before you decide whether or not to take part, it is important for you to understand why the research is being conducted and what it will involve. Please take the time to read the following information carefully and decide if you want to take part in this study. Please feel free to ask questions if there is anything that is not clear or if you would like more information.

What is the purpose of the study? This study involves aims to develop scientific knowledge on emotions and performance.

What does the study involve? You will be asked to perform two tasks: The first task will be the Stroop task, which will require you to decide if the meaning of the bottom words match the print colour and shape presented above, and the second task, virtual reality indoor cycling, will require you to race against virtual competitors while riding on a stationary indoor bicycle. You will be provided with full instructions on how to complete the tasks. We ask that you try to do your best on every task. In addition, you will complete a short questionnaire that assesses your emotion states, before and after the tasks. The entire study will last less than 30 minutes.

Are there any risks involved? You may experience some soreness 24 to 48 hours after riding. The risks can be minimised by warming up beforehand and cooling down afterwards.

What happens to the information I provide? The information you provide will be confidential. The data collected from the research will be anonymised by assigning each participant with a number rather than by name, in accordance with the Data Protection Acts of 1998. Data will be used for research purposes only and confidentiality will be maintained in any publications arising from the study. No one apart from the experimenter (Chris Fullerton) and project supervisors (Professor Andy Lane and Dr Tracey Devonport) will have access to the information you provide. Your consent form will be kept separate from the observations collected during the course of the study. A summary of the results will be available from the experimenter on request once the study is complete.

Do I have to take part? Participation in this study is totally voluntary, you are under no obligation to take part in this study. The data that you provide will be very useful for our study. If you decide to take part you will be given this information sheet to keep and will be asked to sign a consent form. You have the right to withdraw from the study at any time and without giving a reason.

Now is your opportunity to ask any questions about the project.

Thank you for taking the time to read the participant information sheet and considering whether to take part in the project.

If you require any further information, please contact either the investigator (Christopher Fullerton, C.L.Fullerton@wlv.ac.uk) or one of the project supervisors (Prof Andy Lane, 01902 32 2862, A.M.Lane2@wlv.ac.uk and Dr Tracey Devonport, 01902 32 113, T.Devonport@wlv.ac.uk)

Please place a cross in the box to confirm that:

1. I have read and understand the information sheet for the above study and have had opportunity to ask questions ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason ☐
3. I agree to take part in the above study and agree to the terms

If engaging in physical activities:

4. I have completed a pre-exercise health screening form alongside this consent form questions ☐

Name of participant [printed]	**Signature**	**Date**
Investigator [printed]	**Signature**	**Date**

A2. Study 2 Participant Information Sheet and Consent Form

Participant Information and Informed Consent

Primary Researcher: Christopher Fullerton

Supervising Researchers: Professor Andy Lane and Dr Tracey Devonport

Project Title: Can You Maintain Performance in the Face of Crowd Noise?

You are being invited to take part in a research study. Before you decide whether or not to take part, it is important for you to understand why the research is being conducted and what it will involve. Please take the time to read the following information carefully and decide if you want to take part in this study. Please feel free to ask questions if there is anything that is not clear or if you would like more information.

About the study: Intense match situations often generate a mix of pleasant and unpleasant emotions. However, their impact on performance will differ among players; some players will find performing under pressure a challenge and be motivated to perform well, whilst others will feel threatened and struggle to maintain performance. By participating in this study, you will be providing information that may help us better understand the relationship between emotions and performance.

What does the study involve? You will be asked to perform two physical tests: a football passing test followed by a wall squat endurance test. You will be provided with full instructions on how to complete these tasks. In addition you will be asked to complete a short questionnaire before and after each test to assess how you feel. The entire session should take no longer than 30 minutes.

What happens to the information I provide? The information you provide will be confidential. The data collected from the research will be anonymised by assigning each participant with a number rather than by name, in accordance with the Data Protection Acts of 1998. Data will be used for research purposes only and confidentiality will be maintained in any publications arising from the study. No one apart from the experimenter (Chris Fullerton) and project supervisors (Professor Andy Lane and Dr Tracey Devonport) will have access to the information you provide. Your consent form will be kept separate from the observations collected during the course of the study. A summary of the results will be available from the experimenter on request once the study is complete.

Now is your opportunity to ask any questions about the project.

Thank you for taking the time to read the participant information sheet and considering whether to take part in the project.

If you require any further information, please contact either the investigator (Christopher Fullerton, C.L.Fullerton@wlv.ac.uk) or one of the project supervisors (Prof Andy Lane, 01902 32 2862, A.M.Lane2@wlv.ac.uk and Dr Tracey Devonport, 01902 32 113, T.Devonport@wlv.ac.uk)

Please place a cross in the box to confirm that:

5. I have read and understand the information sheet for the above study and have had opportunity to ask questions ☐

6. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason ☐
7. I agree to take part in the above study and agree to the terms

If engaging in physical activities:

8. I have completed a pre-exercise health screening form alongside this consent form questions ☐

Name of participant [printed]	**Signature**	**Date**
Investigator [printed]	**Signature**	**Date**

A3. Study 3 Participant Information Sheet

Participant Information and Informed Consent

Primary Researcher: Christopher Fullerton

Supervising Researchers: Professor Andy Lane and Dr Tracey Devonport

Project Title: How Fast Can You Run 1600 m?

You are being invited to take part in a research study. Before you decide whether or not to take part, it is important for you to understand why the research is being conducted and what it will involve. Please take the time to read the following information carefully and decide if you want to take part in this study. Please feel free to ask questions if there is anything that is not clear or if you would like more information.

About the study: Pacing strategy is important for successful running performance. We are interested in how people select their pacing strategy. By participating in this study, you will be providing information that may help us better understand its relationship with running performance.

What does the study involve?
You will be asked to perform two 1600m trials, with a 10 minute rest period in between. You will be provided with full instructions on how to complete these tasks. In addition you will be asked to complete a short questionnaire before and after each trial. The entire session should take no longer than 30 minutes.

Are there any risks involved? As with all physical activities, there exists the possibility that intense exercise may cause injury. However, you will be asked to warm up prior to your trials and advised to cool down afterwards so as to reduce this risk.

What happens to the information I provide?
The information you provide will be confidential. The data collected from the research will be anonymised by assigning each participant with a number rather than by name, in accordance with the Data Protection Acts (1998). Data will be used for research purposes only and confidentiality will be maintained in any publications arising from the study. No one apart from the experimenter (Chris Fullerton) and project supervisors (Professor Andy Lane and Dr Tracey Devonport) will have access to the information you provide. Your consent form will be kept separate from the observations collected during the course of the study. A summary of the results will be available from the experimenter on request once the study is complete.

Do I have to take part?
The study is voluntary and you will only be included if you give your permission. You are free to withdraw at any time, without giving an explanation.

What next?
If you are interested in taking part or would like to know more about the study, please contact Chris Fullerton via e-mail: C.L.Fullerton@wlv.ac.uk

Now is your opportunity to ask any questions about the project.

Thank you for taking the time to read the participant information sheet and considering whether to take part in the project.

If you require any further information, please contact either the investigator (Christopher Fullerton, C.L.Fullerton@wlv.ac.uk) or one of the project supervisors (Prof Andy Lane, 01902 32 2862, A.M.Lane2@wlv.ac.uk and Dr Tracey Devonport, 01902 32 113, T.Devonport@wlv.ac.uk)
Please place a cross in the box to confirm that:

1. I have read and understand the information sheet for the above study and have had opportunity to ask questions ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason ☐
3. I agree to take part in the above study and agree to the terms

If engaging in physical activities:

4. I have completed a pre-exercise health screening form alongside this consent form questions ☐

Name of participant [printed]	**Signature**	**Date**
Investigator [printed]	**Signature**	**Date**

A4. Study 4 Participant Information Sheet and Consent Form

UNIVERSITY OF WOLVERHAMPTON

Participant Information and Informed Consent

Primary Researcher: Christopher Fullerton

Supervising Researchers: Professor Andy Lane and Dr Tracey Devonport

Project Title: Effect of Sports Drink on Physical and Cognitive Task Performance

We would like to invite you to take part in our research study. Before you decide, it is important for you to understand why this study is being done and what it will involve. Please take the time to read the following information carefully. If anything is not clear or you would like more information, please email us.

About the study
Sports drinks are typically used by athletes during training and competition to enhance performance. The current study investigates the effectiveness of sports drink consumption on performance.

What does the study involve?
You will be asked to perform a high-intensity interval training session on a running track, once a week, for six weeks. The session will consist of 8 x 800m repetitions, with a two-minute rest period. During the rest period you will complete a Stroop task. You will be provided with full instructions on how to complete these tasks. In addition you will be asked to complete a short questionnaire before and after each trial. The entire session should take no longer than 30 minutes.

Are there any risks involved? As with all physical activities, there exists the possibility that intense exercise may cause injury. However, you will be asked to warm up prior to your trials and advised to cool down afterwards so as to reduce this risk.

What happens to the information I provide?
The information you provide will be confidential. The data collected from the research will be anonymised by assigning each participant with a number rather than by name, in accordance with the Data Protection Acts (1998). Data will be used for research purposes only and confidentiality will be maintained in any publications arising from the study. No one apart from the experimenter (Chris Fullerton) and project supervisors (Professor Andy Lane and Dr Tracey Devonport) will have access to the information you provide. Your consent form will be kept separate from the observations collected during the course of the study. A summary of the results will be available from the experimenter on request once the study is complete.
Now is your opportunity to ask any questions about the project.

Thank you for taking the time to read the participant information sheet and considering whether to take part in the project.

If you require any further information, please contact either the investigator (Christopher Fullerton, C.L.Fullerton@wlv.ac.uk) or one of the project supervisors (Prof Andy Lane, 01902 32 2862, A.M.Lane2@wlv.ac.uk and Dr Tracey Devonport, 01902 32 113, T.Devonport@wlv.ac.uk)

Please place a cross in the box to confirm that:

1. I have read and understand the information sheet for the above study and have had opportunity to ask questions ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason ☐
3. I agree to take part in the above study and agree to the terms

If engaging in physical activities:

4. I have completed a pre-exercise health screening form alongside this consent form questions ☐

______________________	______________________	__________
Name of participant [printed]	**Signature**	**Date**
______________________	______________________	__________
Investigator [printed]	**Signature**	**Date**

A5. Study 1 Debrief Sheet

Debrief

Project Title: Effect of Self-Control Resource Depletion on Task Performance

Thank you for taking part in this study. The sheet will provide you will full details of the study in which you participated.

What was the study about?
The purpose of the study was to investigate the effect of exerting self-control on performance. Self-control, often called ‘willpower’, is considered important for achieving long-term goals. It refers to the ability to override an automatic pattern of behaviour with a more desirable course of action. We are testing a particular theoretical model of self-control known as the ‘strength model’. In the model, it is proposed that the ability to successfully self-control depends on some kind of resource which is limited in its supply. It follows that depletion of this resource should impair subsequent self-control performance.

Experimental conditions
You were allocated to an experimental (self-control) group or a control (no self-control) group. The first task required self-control for experimental participants (incongruent Stroop task) and little or no self-control for control group participants (congruent Stroop task). The second task was a cycling task (riding against virtual competitors), which required navigating a virtual course with technical features (e.g., avoiding crashes). This task was the same for all participants. We expected that participants in the experimental group would perform worse on the second task compared to the control group. This is because participants in the experimental group should have reduced self-control ‘strength’ because the first task (Stroop task) required them to expend this self-control resource. Some aspects of the study were withheld from you so that your expectations would not affect the outcome, which is why we presented the tasks as separate experiments. For this reason, we ask that you do not discuss the study with anyone else until its conclusion (dd/mm/yyyy).

Thank you again for taking part. If there is anything you would like to discuss in relation to this study, please feel free to do so by contacting the researchers. If you would like to withdraw your data, please speak to the researcher now or contact him later. The researcher has written your anonymity code on your information sheet. As your data is identified only by this code, you will have to quote it if you want your data to be destroyed at a later date, so please take care not to lose this sheet.

A6. Study 2 Debrief Sheet

Debrief

Project Title: Can You Maintain Self-Control in the Face of Crowd Noise?

Thank you for taking part in this study. The sheet will provide you will full details of the study in which you participated.

What was the study about?
The purpose of the study was to investigate the effect of exerting self-control on performance. Self-control, often called ‘willpower’, is considered important for achieving long-term goals. It refers to the ability to override an automatic pattern of behaviour with a more desirable course of action. We are testing a particular theoretical model of self-control known as the ‘strength model’. In the model, it is proposed that the ability to successfully self-control depends on some kind of resource which is limited in its supply. It follows that depletion of this resource should impair subsequent self-control performance.

Experimental conditions
You were allocated to an experimental (self-control) group or a control (no self-control) group. The first task required self-control for experimental participants (ignoring crowd noise) and no self-control for control group participants (performing the test without crowd noise). The second task was a wall squat endurance task, which required persistence. This task was the same for all participants. We expected that participants in the experimental group would perform worse on the second task compared to the control group. This is because participants in the experimental group should have reduced self-control ‘strength’ because the first task (ignoring crowd noise) required them to expend this self-control resource. Some aspects of the study were withheld from you so that your expectations would not affect the outcome, which is why we presented the tasks as separate experiments. For this reason, we ask that you do not discuss the study with anyone else until its conclusion.

Thank you again for taking part. If there is anything you would like to discuss in relation to this study, please feel free to do so by contacting the researchers. If you would like to withdraw your data, please speak to the researcher now or contact him later. The researcher has written your anonymity code on your information sheet. As your data is identified only by this code, you will have to quote it if you want your data to be destroyed at a later date, so please take care not to lose this sheet.

A7. Study 3 Debrief Sheet

Debrief

Project Title: How Fast Can You Run 1600 m?

Thank you for taking part in this study. The sheet will provide you will full details of the study in which you participated.

What was the study about?
The purpose of the study was to investigate the effect a pacemaker on self-regulation. Planning, maintaining and changing pacing strategy requires self-regulation, which is considered important for endurance performance. We are testing a particular theoretical model of self-control known as the ‘strength model’. In the model, it is proposed that the ability to successfully self-regulate depends on some kind of resource which is limited in its supply. It follows that depletion of this resource should impair subsequent performance.

Experimental conditions
You were allocated to an experimental (pacemaker) group or a control (self-paced) group. The first task required self-control for all participants (self-pacing). The second task was hypothesised to require less self-control (participants ran with a pacemaker) for the experimental participants while the control group participants performed a second self-paced trial. We expected that participants in the self-paced group would perform worse on the second task compared to the pacemaker group. This is because participants in the self-paced group should have reduced self-control ‘strength’ because the first task (self-paced trial) required them to expend this self-control resource. We believe that self-pacing requires more effort (i.e., focusing attention, regulating speed, etc.). Some aspects of the study were withheld from you so that your expectations would not affect the outcome, which is why we presented the tasks as separate experiments. For this reason, we ask that you do not discuss the study with anyone else until its conclusion.

Thank you again for taking part. If there is anything you would like to discuss in relation to this study, please feel free to do so by contacting the researchers. If you would like to withdraw your data, please speak to the researcher now or contact him later. The researcher has written your anonymity code on your information sheet. As your data is identified only by this code, you will have to quote it if you want your data to be destroyed at a later date, so please take care not to lose this sheet.

A8. Study 4 Debrief Sheet

Debrief

Project Title: Does Consuming a Sports Drink Enhance Performance?

Thank you for taking part in this study. The sheet will provide you will full details of the study in which you participated.

What is the research about?
The purpose of the study was to investigate the effect of exerting self-control on performance. Self-control, often called ‘willpower’, is considered important for achieving long-term goals. It refers to the ability to override an automatic pattern of behaviour with a more desirable course of action. We are testing a particular theoretical model of self-control known as the ‘strength model’. In the model, it is proposed that the ability to successfully self-control depends on some kind of resource which is limited in its supply. It follows that depletion of this resource should impair subsequent self-control performance.

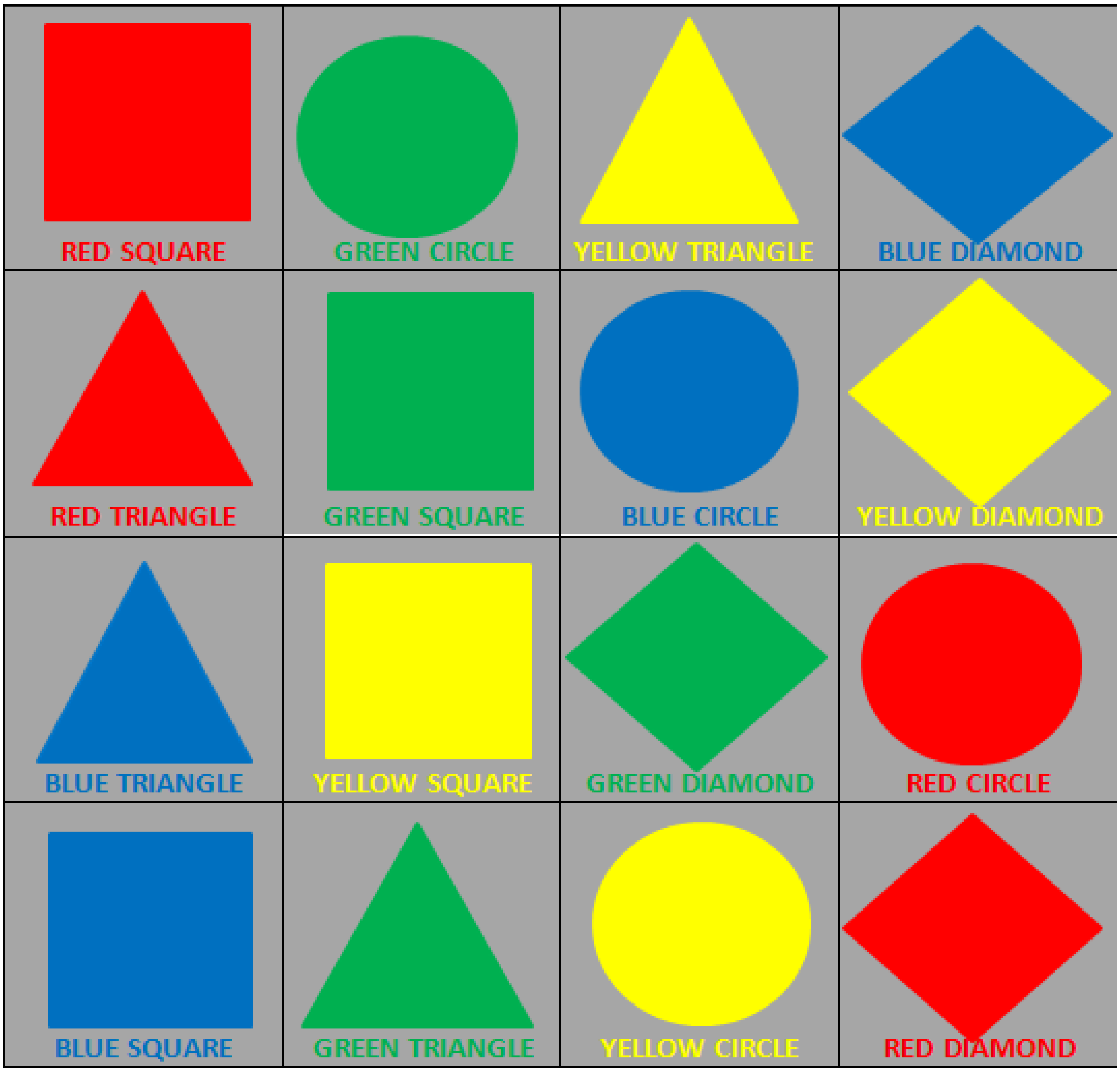
Experimental conditions
You completed six sessions of interval training. For each session you were randomly allocated to an experimental (sports drink) condition or a control (plain water) condition. The session consisted of completing two self-control tasks. The first task, running 800m, was proposed to reduce your self-control strength because high-intensity exercise requires you to self-regulate your effort. The second task, the Stroop task, required you to decide whether the bottom words and ink colour matched the printed shape and ink colour presented above. Making the correct decision requires effort and is thought to deplete your self-control strength. We also assessed emotion. We believe emotion might explain how people are able to maintain performance across consecutive self-control tasks. We expected that the sports drink or plain water would have an effect on emotion which, in turn, could explain the pattern of performance.

Some aspects of the study were withheld from you so that your expectations would not affect the outcome, which is why we presented the tasks as separate experiments. For this reason, we ask that you do not discuss the study with anyone else until its conclusion.

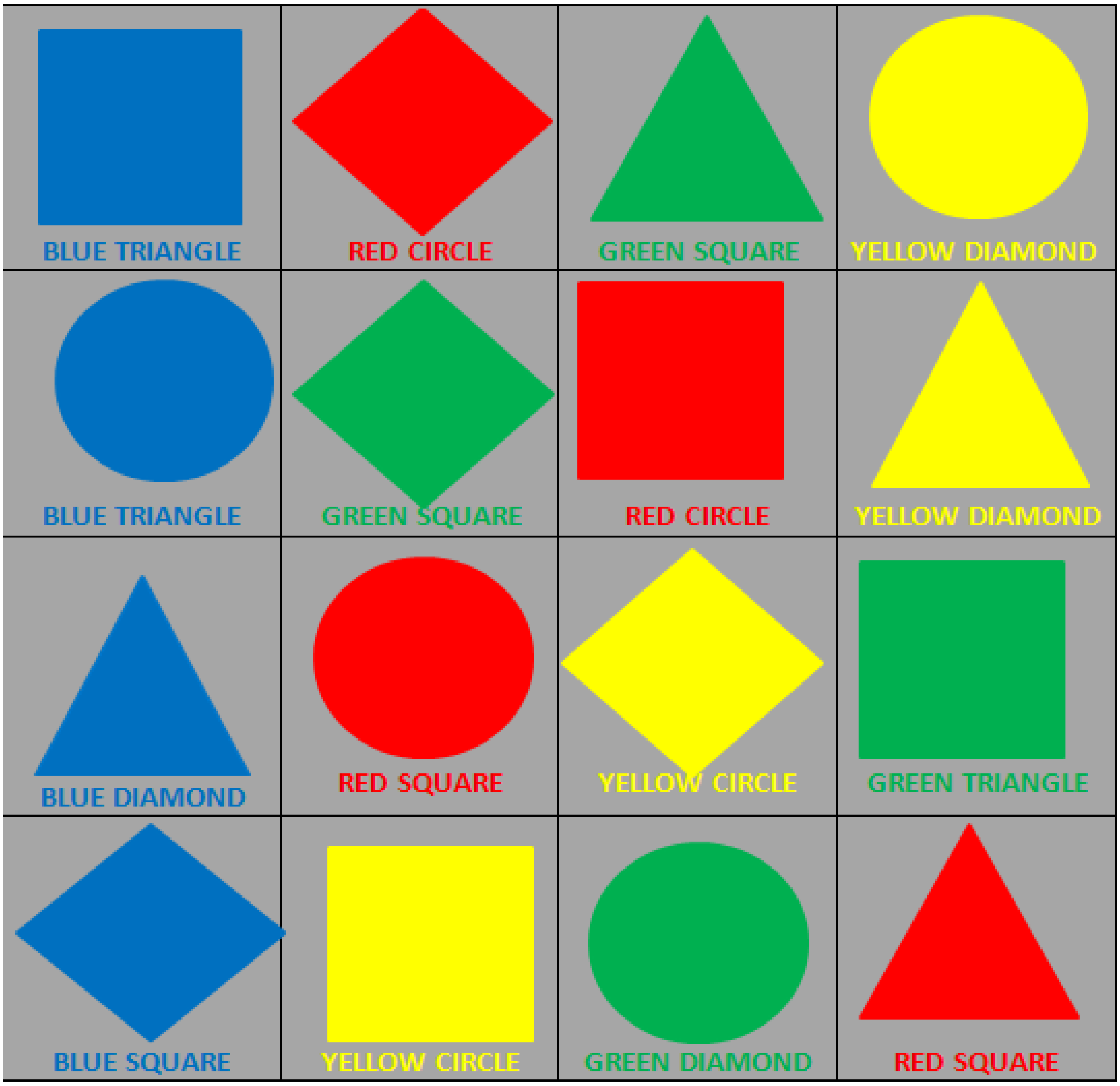
Thank you again for taking part. If there is anything you would like to discuss in relation to this study, please feel free to do so by contacting the researchers. If you would like to withdraw your data, please speak to the researcher now or contact him later. The researcher has written your anonymity code on your information sheet. As your data is identified only by this code, you will have to quote it if you want your data to be destroyed at a later date, so please take care not to lose this sheet.

Appendix B: Stroop Tasks

B1. Congruent Stroop task



B2. Incongruent Stroop task



Appendix C: Study 3 Questionnaires

C1. Pre-Trial Questionnaire

<u>How Do You Expect to Perform?</u>

1. ***What time have you set as a goal for today's 1600 m? ___________*** *min/secs*

2. ***Rate your degree of confidence to achieve this time by recording a number from 0 to 100 using the scale given below:***

0	10	20	30	40	50	60	70	80	90	100
Cannot do at all					Moderately certain can do					Highly certain can do

3. ***My pacing strategy for the 1600m is to:***

Run 4 even-paced laps?	☐
Run the 1st and 4th lap faster with 2 even middle laps	☐
Go off as fast as possible from the start and try to hold on	☐
Go off steady and go faster near the end	☐
Run a faster second ½ than the first	☐
Other?	☐

4. ***Rate your degree of confidence to adhere to this pacing strategy by recording a number from 0 to 100 using the scale given below****:*

0	10	20	30	40	50	60	70	80	90	100
Cannot do at all					Moderately certain can do					Highly certain can do

5. ***How difficult will it be to be able to follow this strategy?***

Very easy										Very difficult
0	1	2	3	4	5	6	7	8	9	10

6. How do you feel right now?

	Not at all			Moderately				Extremely
Happy	0	1	2	3	4	5	6	7
Anxious	0	1	2	3	4	5	6	7
Dejected	0	1	2	3	4	5	6	7
Energetic	0	1	2	3	4	5	6	7
Fatigued	0	1	2	3	4	5	6	7
Angry	0	1	2	3	4	5	6	7
Excited	0	1	2	3	4	5	6	7

C2. Post-Trial Questionnaire

<u>How Well Did You Perform?</u>

We want you to think about how well you performed and give some reasons why that was the case.

1. ***What time did you do?___________ min/secs***

2. ***How well did you run?***

Very poorly										Very well
0	1	2	3	4	5	6	7	8	9	10

3. ***Did you achieve your mile goal?*** If yes, please look at the reasons given and circle which best describes why you did/ not achieve your goal today:

Yes I achieved my goal and I think it was because:		*No, not this time!*	
I performed really well		I performed badly	
My goal was realistic but challenging		My goal was realistic and challenging but I just missed out for some reason	
My goal was probably too easy		Goal was unrealistic and not attainable	
Another reason? Please describe		Other – please specify	

4. **About each lap.**

Rate how well you performed on each lap. For each lap, please tick whether you ran: 1) too fast, 2) the pace was about right, or 3) the pace was too slow.

	Too fast	About right	Too slow	Comments
Lap 1				
Lap 2				
Lap 3				
Lap 4				

5. Rate how each lap felt *(Please tick).*

Rating	Description	Lap 1	Lap 2	Lap 3	Lap 4
0	Nothing at all				
0.5	Very, very light				
1	Very light				
2	Fairly light				
3	Moderate				
4	Somewhat hard				
5	Hard				
6					
7					
8					
9					
10	Very, very hard (Maximal)				

6. How do you feel right now*? (Please circle)*

	Not at all			Moderately				Extremely
Happy	0	1	2	3	4	5	6	7
Anxious	0	1	2	3	4	5	6	7
Dejected	0	1	2	3	4	5	6	7
Energetic	0	1	2	3	4	5	6	7
Fatigued	0	1	2	3	4	5	6	7
Angry	0	1	2	3	4	5	6	7
Excited	0	1	2	3	4	5	6	7

Appendix D: Emotion Scales

Items taken from Sport Emotion Questionnaire (SEQ; Jones, Lane, Bray, Uphill, & Catlin, 2005)

Below you will find a list of words that describe a range of feelings that sport performers may experience. Please read each one carefully and indicate on the scale next to each item how you feel **right now, at this moment, in relation to the *previous repetition***. There are no right or wrong answers. Do not spend too much time on any one item, but choose the answer which best describes your feelings right now in relation to the previous repetition.

	Not at all			Moderately				Extremely
Happy	0	1	2	3	4	5	6	7
Anxious	0	1	2	3	4	5	6	7
Guilty	0	1	2	3	4	5	6	7
Energetic	0	1	2	3	4	5	6	7
Fatigued	0	1	2	3	4	5	6	7
Angry	0	1	2	3	4	5	6	7
Excited	0	1	2	3	4	5	6	7

Appendix E: How Should I Regulate My Emotions If I Want to Run Faster?

The following chapter has been published in the following manuscript: Lane, A. M., Devonport, T. J., Friesen, A. P., Beedie, C. J., Fullerton, C. L., & Stanley, D. M. (2016). How should I regulate my emotions if I want to run faster? *European Journal of Sport Science, 16*(4), 465-472.

Abstract

The present study investigated the effects of emotion regulation strategies on self-reported emotions and 1600 m track running performance. In stage 1 of a three-stage study, participants (N= 15) reported emotional states associated with best, worst and ideal performance. Results indicated that a best and ideal emotional state for performance composed of feeling happy, calm, energetic and moderately anxious whereas the worst emotional state for performance composed of feeling downhearted, sluggish and highly anxious. In stage 2, emotion regulation interventions were developed using online material and supported by electronic feedback. One intervention motivated participants to increase the intensity of unpleasant emotions (e.g., feel more angry and anxious). A second intervention motivated participants to reduce the intensity of unpleasant emotions (e.g., feel less angry and anxious). In stage 3, using a repeated measures design, participants used each intervention before running a 1600 m time trial. Data were compared with a no treatment control condition. The intervention designed to increase the intensity of unpleasant emotions resulted in higher anxiety and lower calmness scores but no significant effects on 1600 m running time. The intervention designed to reduce the intensity of unpleasant emotions was associated with significantly slower times for the first 400 m. We suggest future research should investigate emotion regulation, emotion and performance using quasi-experimental methods with performance measures that are meaningful to participants.

Evidence indicates that self-reported emotions are predictive of performance (Beedie, Terry, & Lane, 2000; Hanin, 2003, 2010; Lazarus, 2000), and that athletes engage in strategies to regulate their emotions in order to enhance performance (Lane, Beedie, Jones, Uphill, & Devonport, 2012; Wagstaff, 2014). Although emotion regulation is relevant to all sports, in endurance performance, emotion regulation and fatigue regulation are highly intertwined. Noakes (2012) argued “fatigue is principally an emotion, part of a complex regulation, the goal of which is to protect the body from harm” (p. 2). Evidence demonstrates that runners use emotion regulation strategies without formal training, and that many of these resemble traditional psychological skills such as imagery, self-talk and goal setting (Stanley, Lane, Beedie, & Devonport, 2012).

Lane et al. (2012) argued there are at least two distinct motivations to regulate emotion—hedonic and instrumental. Hedonic emotion regulation is characterised by trying to increase the intensity of pleasant emotions and reduce the intensity of unpleasant emotions. A great deal of research suggests that this approach to emotion regulation could yield positive performance (Beedie et al., 2000; Hanin, 2010; Morgan, 1980; Raglin, 2001). In contrast, an instrumental approach to emotion regulation is one in which an athlete seeks to feel emotions that will help performance. For example, some athletes believe that anxiety enhances performance and will up-regulate that emotion accordingly whilst others believe anxiety hampers their performance and attempt to reduce its intensity (Hanin, 2010; Lane, Beedie, Devonport, & Stanley, 2011; Stanley, Beedie, Lane, Friesen, & Devonport, 2012; Stanley, Lane et al., 2012).

Emotion regulation during endurance sport is proposed to be influenced by progress towards goal achievement (Beedie, Lane, & Wilson, 2012; Baron, Moullan, Deruelle, &

Noakes, 2011; Noakes, 2012; Lane, 2001; Wilson, Lane, Beedie, & Farooq, 2012). Lane (2001) reported that an emotional state comprising anger, tension and vigour associated with high goal-confidence, while depressed mood and very high tension associated with low goal-confidence. Lane (2001) reported high scores of emotional intelligence associated with pleasant emotions in a multi-stage marathon race. Wilson et al. (2012) conducted an experimental study where participants were provided false feedback by informing riders that they were 5% behind (negative) or ahead (positive) of their self-set goal. Compared to false-positive feedback conditions, false-negative feedback is associated with an unpleasant emotional profile characterised by higher anxiety, anger, and sadness. Further, it is also associated with higher lactate and oxygen usage. False negative feedback also produced an erratic pacing strategy compared to false-positive feedback. In negative feedback conditions, participants attempted to ride faster, producing spikes showing high power output, followed by periods of low power output. However, despite different pacing strategies between conditions, no significant difference in completion time was found between false-negative and false-positive conditions.

An optimal pacing strategy is one that ensures that energy expenditure is appropriately regulated (Tucker & Noakes, 2009). Such regulation is probably a learned pattern, determined by an athlete's perceptions of the intensity required to complete a defined distance as fast as possible—a process that is influenced by past experiences (Micklewright, Papadopoulou, Swart, & Noakes, 2010) and emotions (de Koning et al., 2011; Tucker & Noakes, 2009). A key factor determining the pacing strategy favoured is the duration of the exercise bout.

Although an even-paced strategy has been suggested to be the optimal pacing strategy, it appears that best performance is achieved by a maximal start and progressive slowing down for shorter duration track running events (Tucker, Lambert, & Noakes, 2006). In contrast, middle and long-distance events are characterised by a fast start, a period of slower running and increase in speed towards the end (Noakes, Lambert, & Hauman, 2009; Tucker et al., 2006). In such events, evidence shows that pacing strategies differ for World Records in comparison to Olympic track finals (Thiel, Foster, Banzer, & De Koning, 2012). In World record and personal best runs, performances suggest smooth and slow transitions of speed, which is more in keeping with a constant pace. With regard to a fast-start, fast-finish strategy, if negative feedback leads to increased anger and anxiety, which in turn associates with bursts of effort, then unpleasant emotions could be helpful. Extending this logic to methods an athlete might use to develop his/ her own emotion regulation strategies, if they believe anxiety helps performance (Hanin, 2010; Lane et al., 2011), then arguably, negative self-talk might help her or him perform better via repeated bouts of intense effort.

The aim of the present study was to extend examination of emotion regulation and pacing in cycling (Beedie et al., 2012; Wilson et al., 2012) to running performance. In contrast to the deceptive methods used by Beedie et al. (2012), the present study used guided self-regulatory methods to alter emotion. The approach is a logical extension of previous research as evidence shows runners use self-regulation strategies as part of preparation for competition (Stanley, Beedie et al., 2012; Stanley, Lane et al., 2012). We investigated the effects of strategies designed to increase or decrease the intensity of unpleasant emotions, on emotion, pacing strategy and overall 1600 m track running performance. Hypothetically high anxiety or anger would lead to a fast first 400 m.

However, in terms of overall 1600 m performance, we hypothesised that overall finish times would not be significantly different between conditions, a finding consistent with Beedie et al. (2012).

Method

Participants

Fifteen runners (Male: $n = 8$, Female: $n = 7$; M_{age} 27.41 years, $SD = 8.44$ years) participated in the present study. The inclusion criteria was as follows: participants needed to be runners who trained regularly, as defined by engaging in more than one training session per week, and had race experience, defined as having raced in the previous 12 months. Participants were recruited via the project website, which indicated that they would need to run three 1600 m time trial runs in one session. Participants reported competing in events ranging from 5 km to marathon distances and running an average of 20.55 miles ($SD = 19.75$ miles) per week, hence the distribution in training status varied. None of the participants had previously worked with a sport psychologist.

Measures

Emotions. Emotions measured were: “Calm”, “Happy”, “Energetic”, “Sluggish”, “Downhearted”, “Angry” and “Anxious” taken from a previously validated scale (Terry, Lane, & Fogarty, 2003). The scale was purposefully short as participants completed this measure six times over the duration of the data collection session. The scale was used to assess emotion associated with best and worst performance and was also completed prior to each of three 1600 m time trials.

Performance. Performance was a 1600 m maximal time trial on a standard 400 m outdoor running track. Time was recorded for each 400 m to facilitate examination of pacing strategy. We compared actual lap time with the average lap time (run time/4) calculated from total 1600 m completion time.

Procedure

Following institutional ethical approval, participants were recruited into the present study via a link hosted on the Runners World website and the website of the research team. The study was then conducted in three distinct stages. The purpose of stage 1 was to establish emotions associated with best and worst performance for each participant (Hanin, 2010). The rationale for this process was to facilitate the development of an individualised emotion regulation intervention for each participant. Participants completed an informed consent form and provided demographic information including previous running experience. They then recalled emotions associated with best and worst running performance using the emotion scale used in the present rather than a user-generated list as typically done by Hanin (2010). They also estimated an emotional state that they believed represented an ideal, one in which they would produce a peak performance. Participants were provided with personal feedback via email describing the emotional state associated with best, worst and ideal performance.

When seen collectively, there were large differences in emotions proposed to be associated with ideal, best and worst performance (Wilks' Lambda = .66, $p < .001$, $\eta_p^2 = .34$), with a significant difference between each condition (Best versus ideal: Wilks' Lambda = .30, $\eta_p^2 = .70$, $p < .001$; Best versus worst: Wilks' Lambda = .28, $\eta_p^2 = .71$, p < .001; Worst versus ideal: Wilks' Lambda = 19, $\eta_p^2 = .81$, $p < .001$, see Figure 1, Table 1).

The emotional state associated with ideal performance was characterised by feeling happier, calmer and more energetic, less anxious, sluggish and downhearted than emotions associated with best and worst performance (Figure 1). This suggested that regulation efforts should be motivated towards reducing the intensity of unpleasant emotions. However, the notion that unpleasant emotion might help performance was evident in the anxiety data where results suggest that moderately intense anxiety is associated with best performance (see Figure 1).

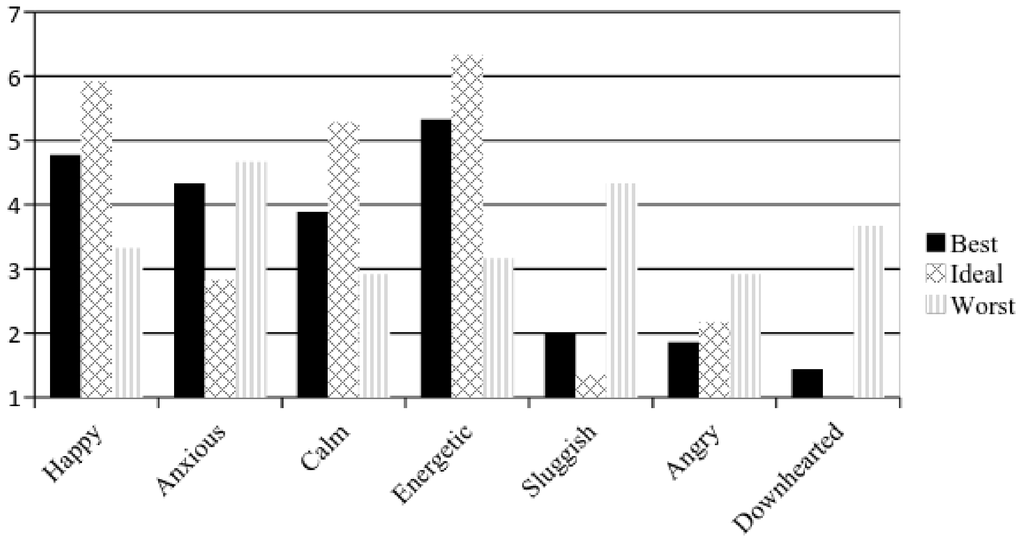


Figure 1. Emotional responses with reference to best, ideal and worst performance

Table 1

Emotion Scores for Best performance, Ideal Performance and Worst Performance (range 1-7)

	Best vs Worst vs. Ideal		Best vs. ideal		Best vs. worst		Worst vs. ideal	
	$F_{3,42}$	η_p^2	$F_{3,42}$	η_p^2	$F_{3,42}$	η_p^2	$F_{3,42}$	η_p^2
Happy	35.21*	0.50	36.89*	.51	17.23*	.34	53.07*	.61
Anxious	14.84*	0.30	21.75*	.38	0.73	.02	26.15*	.44
Calm	23.46*	0.40	23.69*	.40	6.81*	.17	34.76*	.51
Energetic	51.32*	0.59	12.86*	.27	48.94*	.60	73.97*	.69
Sluggish	45.89*	0.57	5.84**	.14	39.8*	.55	67.81*	.67
Angry	5.00*	0.12	.37	.01	0.98	.03	4.19**	.11
Downhearted	49.60**	0.59	14.06*	.29	36.85*	.53	65.89*	.66

**p* < .01, ** p < .05

The aim of stage 2 was to develop personal emotion regulation interventions. Participants were asked to reflect on their emotional profiles and consider what strategies they use to regulate emotions in training and competition (see Stanley, Beedie et al., 2012). Material to support these reflections was made available via a video hosted on the project website and YouTube (https://www.youtube.com/watch?v=TJDti3Z_WW8). Feedback was provided electronically via email. As expected, and consistent with findings reported by Stanley, Beedie et al. (2012), participants reported strategies that they used to modify emotions. For example, in order to decrease the intensity of unpleasant emotions, participants reported changing perspective and modifying physiological manifestations of emotions via, for example, deep breathing. To increase the intensity of unpleasant emotions, participants reported reappraisal of the situation by raising its importance. They indicated that the challenge was not to raise anxiety, but to regulate it to an optimum. Participants reported meta-emotional beliefs that anxiety can help energize them for a good performance. However, participants also noted that getting the balance just right between optimal levels of anxiety and excessive anxiety was difficult to attain.

The aim of stage 3 was to use quasi-experimental methods to test the effectiveness of emotion regulation interventions developed in stage 2. A no-treatment condition was used as a control. Participants completed three 1600 m time trials. They received no verbal feedback relating to their performance and no time data. All trials were undertaken individually so as not to introduce interpersonal competition. Although weather conditions varied, the emphasis of the analysis is on within-subject variation and therefore adverse weather did not adversely influence the aim of the study. Each participant completed 3 x 1600 m in similar conditions. Each participant was advised that testing could take one hour of their time. The order in which the interventions were presented was randomised. After using an emotion regulation strategy (where applicable) participants rated their emotional state. Results revealed that there was no significant order effect (Wilks' Lambda = .68, η_p^2 = .17, p = .47).

Results

Effects of interventions on self-reported emotions. Repeated measures multivariate analysis of variance indicated a significant intervention effect (Wilks' Lambda $_{14,66}$ = .38, *p* = .002, η_p^2 = .38) for differences in emotion between intervention and no treatment conditions. Follow-up analysis (see Table 2) indicated higher anxiety and lower calmness following an intervention designed to increase the intensity of unpleasant emotion. However, there were no significant differences in emotions between no-treatment and unpleasant emotion reduction conditions.

Table 2

Emotions States Before Each Time Trial by Intervention Condition

	Control /No treatment		Increase unpleasant emotion		Decrease unpleasant emotion				
	M	*SD*	*M*	*SD*	*M*	*SD*	$F_{3,42}$	*p*	η_p^2
Anxious	3.07	1.09	4.54	1.16	2.82	0.53	12.75	.00**	.40
Happy	5.00	1.038	4.57	1.60	5.00	.96	.56	.57	.03
Calm	4.29	1.68	2.86	1.66	4.93	1.64	5.710	.01**	.23
Energetic	4.79	1.31	4.57	1.70	4.14	1.29	.718	.49	.04
Sluggish	1.79	0.80	2.36	1.28	2.64	1.55	1.71	.19	.08
Anger	1.00	0.00	2.00	1.66	1.50	0.94	2.87	.07	.13
Downhearted	1.07	0.27	1.64	1.08	1.50	1.09	1.53	.23	.07

**p < .001

Effects of interventions on 1600 m running performance. Repeated-measures ANOVA results indicated no significant intervention effect. Therefore compared to no-treatment, interventions did not significantly improve or worsen 1600 m running time, $F(2,41) = .26$, $p = .78$. However, results indicated significant interaction effects $F(3,37) = 5.75$, $p < .001$,

$\eta_p^2 = .29$. As Figure 2 indicates, interventions designed to reduce the intensity of unpleasant emotion were associated with significantly slower running times for the first 400 m compared to the interventions designed to increase the intensity of unpleasant emotion and no-treatment. Results indicated that there was a main effect for pacing with participants recording faster times for the first 400 m, slower times for laps 2 and 3 with a faster time for the final 400 m, $F(3,37) = 35.05$, $p < .001$, $\eta_p^2 = .74$.

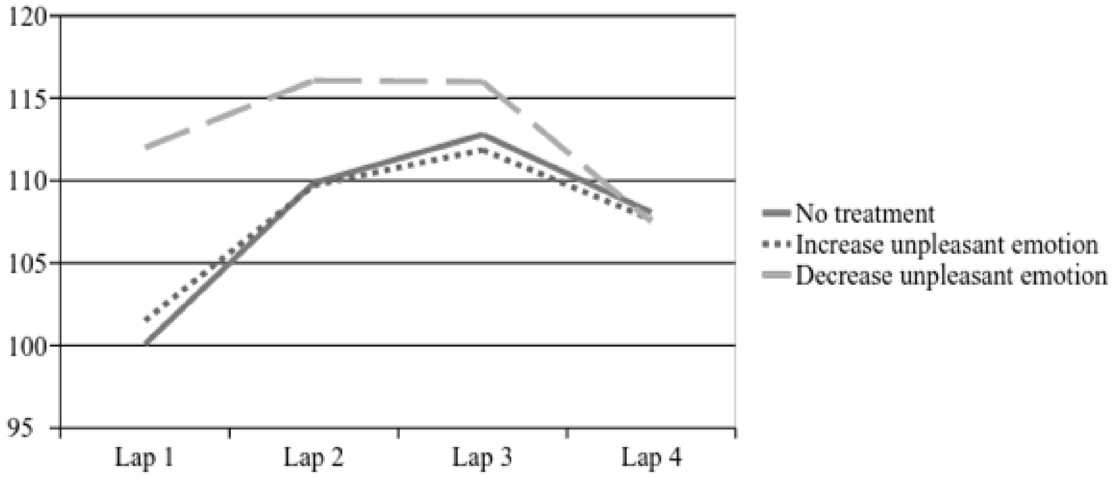


Figure 2. 400m lap times by intervention condition

Discussion

The present study investigated the effects of strategies designed to increase or decrease the intensity of unpleasant emotions, on emotion, pacing strategy and overall 1600 m track running performance. Previous research has found that emotions influence performance (Beedie et al., 2000; Hanin, 2003, 2010; Lazarus, 2000), and emotion regulation strategies are a common approach to mental preparation (Lane et al., 2012; Wagstaff, 2014). Data indicate that an intervention designed to raise the intensity of unpleasant emotion led to increased anxiety and reduced calmness in comparison to the no-treatment and intervention to reduce the intensity of unpleasant emotion condition. No significant difference in the intensity of emotions was observed between the intervention designed to reduce the intensity of unpleasant emotion and the no-treatment condition. We suggest that in the no-treatment conditions, a number of non-conscious emotion regulation strategies were employed which served to regulate emotion to the ideal emotional state.

During the development of the interventions, participants reported that regulating anxiety via reducing its intensity was a common approach, and therefore it was possible that the no-treatment condition was contaminated with well-learned and possibly automated strategies used to reduce the intensity of anxiety. As Stanley, Beedie et al. (2012) report, there are many thoughts and actions that act as emotion regulation strategies that athletes might not recognize as such. For example, warming up is done ostensibly to prepare for physical performance, but in doing so, warming up might increase beliefs in readiness to perform and reduce anxiety. Lane (2001) found that perceived readiness to perform associated with pleasant emotions with perceived readiness a factor comprising perceptions of physiological states. In the present study, emotion regulation interventions involved active training such as intentionally saying words to oneself or via imagery. Thus warming up could have acted as an emotion regulation treatment.

In terms of the effects on performance, results suggest that emotion regulation strategies did not significantly improve or worsen time to complete 1600 m, a finding consistent with previous research (Beedie et al., 2012; Wilson et al., 2012). Interrogation of performance involved investigating the effects of emotion regulation on the intensity of pre-run emotions and pacing. In the present study, the pacing strategy followed in each condition was to run a faster time for the first 400 m, slower times for laps two and three and a faster time for the final lap (see Figure 2). However, although there was no significant difference in finish time to complete the 1600 m, reducing the intensity of unpleasant emotions condition was associated with higher calmness and running a slower first 400 m and overall a more consistent pacing strategy than the other two conditions. However, following the above strategy did not associate with lower anxiety than following the no-treatment conditions, and the pacing strategy in the no-treatment condition also associated with running first lap time at a similar speed to the increasing unpleasant emotion condition. Hence, it appears the emotion regulation intervention influenced emotions experienced and the pacing strategy, but not the overall performance.

Although fast start and finish approach to pacing is consistent with those reported for successful performance in middle distance performance (de Koning et al., 2011; Noakes et al., 2009; Thiel et al., 2012), it also associates with the highest ratings of perceived exertion. Research indicates that intense fatigue associates with a combination of unpleasant emotions and thoughts that signal stopping or slowing down (Micklewright et al., 2009; Noakes, 2012). Noakes argues that emotions and fatigue act as a safety valve to provide information that the individual is not coping physiologically, thereby prompting a response. Clearly, following this pacing strategy would require participants to have a high level of motivation to try to run fast when experiencing intense sensations of fatigue, and overriding the signal to slow down goes against an evolved mechanism for survival (Baron et al., 2011; Noakes, 2012).

The ability to follow a pacing strategy over the first part of the run before fatigue becomes the salient feeling is clearly important. The self-regulatory component of pacing is important as an athlete makes judgments as to whether performance will meet expectations using ongoing feedback. In the present study, participants had neither access to their running time nor could they attempt to gauge pace by following other runners, and so relied on ongoing metabolic and cardiorespiratory feedback. Previous research has reported that in the absence of feedback, participants reported increased unpleasant emotions. For example, in the no-feedback condition, Beedie et al. (2012) reported that ongoing emotions were similar to those experienced in a negative feedback condition where participants experienced intense anxiety. We suggest that the absence of feedback during the run could have acted as a stressor and contributed to results showing similar data between the increasing the intensity of unpleasant emotions and no-treatment conditions. We suggest that future research should examine the effects of ongoing feedback and assess emotions within performance. One way of helping an athlete pace a run is to allow them to be paced by another runner. The use of pacers would allow runners to control pace in order to counteract the effects of anxiety of pace judgment.

In the present study, we attempted to develop individualised emotion regulation interventions by guiding participants to develop and refine the strategies that they already used (Stanley, Beedie, et al., 2012). This followed a process suggested in a recent review by Lane et al. (2012). The interventions used to guide emotion regulation were developed via electronic communication. This approach minimises possible practitioner effects (Andersen, 2006). Although not commonly used in sport psychology, evidence from other areas of application lends support to the utility of online support (Gaffney, Mansell, Edwards, & Wright, 2013). We suggest further research is needed to investigate the efficacy of brief interventions delivered electronically. If such interventions were found to be effective, then it would be possible to provide resources that allow athletes to self-regulate their emotions.

Cugelman, Thelwall, and Dawes (2011) argued that with over 2 billion internet users, the potential reach of interventions is huge. The present study represents a start point to that process and future research should look to increase the sophistication of the intervention used and offer standardised feedback (Gaffiney et al., 2013).

A desirable feature of the present study is the use of a quasi-experimental design. A great deal of emotion research has used a correlational design. Michie, Rothman, and Sheeran (2007) examined the utility of research designs to test interventions in health and argued that control group data are necessary to control for effect of intention on behaviour. Correlational studies cannot rule out the possibility that intention caused behaviour change (Webb & Sheeran, 2006) and a great deal of research on emotion in sport has used a correlational design (Hanin, 2010; Lane et al., 2012). The present study developed an individualised intervention that not only formed part of a scientific study, but also was also useful for participants. The present study tested the effects of the intervention, although an acknowledged limitation is that multiple measures were not used for each condition. We suggest that the method of developing an emotion regulation strategy and testing it in controlled conditions such as track running could be something participants could do as a regular part of training.

An acknowledged limitation is the small and heterogeneous nature of the participant sample (in experience and level of performance). We suggest future research should investigate extremes of the population separately. For experienced runners, research should investigate the use and effectiveness of existing self-regulation strategies on managing anxiety and its resultant impact on performance. For inexperienced athletes, research should investigate the effects of anxiety on performance, and explore the strategies people use to manage emotions. Given research evidencing dropout among inexperienced athletes (Dishman, 1982), it would be prudent to examine the extent to which these describe thoughts related to wishing to cease running. A second limitation is that testing was done on one day and residual effects of one intervention on another and fatigue could have been influential. Although evidence found no significant order effect, holding data collection on different days would seem prudent.

The one practical recommendation stemming from the present study is to that participants should investigate the effects of self-help interventions as part of their training. A participant could replicate the present study with minimal support from others, and via using such methods identify the intervention that helps him/ her feel and perform better. Evidence shows runners use self-regulation strategies as part of mental preparation (Stanley, Beedie et al., 2012), although they do not have systematic methods to evaluate the effectiveness of these strategies. One implication of the present study is that athletes should use systematic methods to assess the effectiveness of self-regulatory interventions.

In conclusion, the present study examined the effects of interventions to intensify or dampen unpleasant emotion before running a 1600 m maximal time trial. Results show that participants could enact interventions to alter anxiety and calmness. It is suggested that future research examines the use of strategies intended to help athletes perform optimally by using a pacing strategy that serves their goals.

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Appendix F: Introducing Sport Psychology Interventions: Self-Control Implications

The following chapter has been published in the following manuscript: Devonport, T., Lane, A., & Fullerton, C. L. (2016). Introducing sport psychology interventions: self-control implications. *The Sport Psychologist, 30*, 24-29.

Abstract

Evidence from sequential-task studies demonstrate that if the first task requires self-control, then performance on the second task is compromised (Hagger, Wood, Stiff, & Chatzisarantis, 2010). In a novel extension of previous sequential-task research, the first self-control task in the current study was a sport psychology intervention, paradoxically proposed to be associated with improved performance. Eighteen participants (9 males, 9 females; mean age = 21.6 years, *SD* = 1.6), none of whom had previously performed the experimental task or motor imagery, were randomly assigned to an imagery condition or a control condition. After the collection of pre-test data, participants completed the same 5-week physical training program designed to enhance swimming tumble-turn performance. Results indicated that performance improved significantly among participants from both conditions with no significant intervention effect. Hence, in contrast to expected findings from application of the imagery literature, there was no additive effect after an intervention. We suggest practitioners should be cognisant of the potential effects of sequential tasks, and future research is needed to investigate this line of research.

One role of sport psychologists working with teams or individuals is to enhance psychological aspects that influence sports performance (Williams & Straub, 2010). In doing so, sport psychologists might typically focus on improving psychological skills. Weinberg and Gould (2007) defined psychological skills training as a "systematic and consistent practice of mental or psychological skills for the purpose of enhancing performance, increasing enjoyment, or achieving greater sport and physical activity self-satisfaction" (p. 250). One psychological skill commonly addressed by sport psychologists is motor imagery, which is the mental representation of a movement or action without any corresponding body movement (Guillot & Collet, 2005; Wakefield, Smith, Moran, & Holmes, 2013). Motor imagery is a mental skill used by many athletes to facilitate sport performance (Guillot & Collet, 2008), and specifically swimming, the focal sport of the current study (Post, Muncie, Cruces, & Simpson, 2012).

In a survey of psychological skills use, Jowdy, Murphy and Durtschi (1989) found imagery techniques are regularly used by 100% of consultants, 90% of athletes, and 94% of coaches sampled. Imagery is arguably the most widely practiced psychological skill used in sport; athletes believe that it benefits performance (Hall, Mack, Paivio, & Hausenblas, 1998; Jowdy et al., 1989). Therefore, imagery is proposed to be a useful skill to teach athletes beginning psychological skills training.

Although motor imagery has been proposed to lead to improved performance, this is not always the case, especially when people are beginning to use it (Cumming & Williams, 2012). One argument forwarded to explain this finding has been failure to effectively capture images. For example, comparisons between expert and novice athletes demonstrate different patterns of brain activation during motor imagery of a corresponding task. This is proposed to arise from the fact that experts find it easier to visualize an action because they see/experience the action extensively in daily life (Debarnot, Sperduti, Di Rienzo, & Guillot, 2014). A second theory that might explain the finding that imagery may not always benefit performance is the strength model of self-control (Baumeister, Vohs, & Tice, 2007). Self-control is conceptualised as the deliberate act of overriding habitual behavioural responses, which means the person exerts effort to bring about change. For self-control theory to explain why imagery might not be effective, it is important to be cognisant of theory and methods that have been used in the social psychology literature (Baumeister et al., 2007; Hagger et al., 2010).

Central to the model is the hypothesis that engaging in an initial self-control task uses and thereby reduces available resources, leading to worse performance on subsequent tasks. Baumeister et al. (2007) referred to this process as *depletion* on the basis of an assumption that the resources available were constant, and therefore reduction implies depletion. When this theory and method are applied to learning new skills, including psychological skills such as imagery (which is a complex skill), learning is likely to take time and effort. According to a wealth of experimental data using a sequential-task design (Hagger et al., 2010), if imagery is a self-control task, then it would deplete resources and lead to the availability of fewer resources for subsequent tasks. An important aspect of the sequential task model is the fact that the second task is performed shortly after the first; that is, there is not a sufficient recovery period. In the experimental tasks that provide support for the strength model, participants performed two tasks, one after the other. A limitation is that the time between tests is rarely reported. The implication is that it is done minutes or seconds later, possibly analogous to performing imagery shortly before performing a motor skill, such as a swimming tumble turn.

We suggest research findings regarding depletion effects could have significant practical implication for sport and exercise psychologists looking to introduce unfamiliar psychological skills to athletes. The implication is that individuals engaging in two self-control tasks, one after another, are at risk of performance on the second task being compromised. For example, an athlete asked to perform motor imagery and then immediately perform a physical skill also requiring self-control is completing two sequential self-control tasks, whereas an athlete just performing the physical skill is doing one. Applying findings of the strength model to this scenario, we would predict that the second athlete would perform better on the physical skill (i.e., in terms of technical and outcome proficiency) than the first because they have not depleted resources in undertaking a prior self-control task.

It is acknowledged that motor imagery may be undertaken away from physical practice and actual performance (Smith, Wright, & Cantwell, 2008) and thus does not offer a sequential task design. However, motor imagery can immediately precede motor skill execution (Battaglia et al., 2014), or follow a combination of independent use and usage immediately before execution (Post et al., 2012). In which case, this offers a sequential task. As such, the aim of the current study was to examine the potential paradox in which psychological skills interventions impair performance via depletion effects. This study involved a sample of participants learning two new tasks: (a) imagery and (b) a motor skill. This sequential-task design was used to examine how exertion of self-control on an initial motor imagery task affected the subsequent performance of a novel motor skill. We set two hypotheses (Guillot & Collet, 2005; Wakefield et al., 2013). First, in accordance with the imagery literature, we hypothesised that imagery would lead to improved performance on the experimental motor task. Second, in contrast, and as proposed by the self-control literature (Baumeister et al., 2007), we hypothesised that imagery would deplete resources and performance would deteriorate on the second performance of the experimental motor task.

Method

Participants

Eighteen volunteer participants (nine males, nine females; mean age = 21.6 years, *SD* = 1.6), none of whom had previously performed the self-control task (motor imagery of the front crawl tumble turn) or the experimental motor task (front crawl tumble turn) took part in the current study. All participants consented participation and were free to withdraw consent at any time.

Measures

The Movement Imagery Questionnaire (MIQ; Hall & Pongrac, 1983) was used to assess participants' imagery ability. The MIQ presents nine imagery tasks, each of which is imagined once using the visual sense and once using the kinaesthetic sense. For example:

Starting position. Stand with your feet slightly apart and your arms fully extended above your head.

Action. Slowly bend forward at the waist and try and touch your toes with your fingertips (or if possible, touch the floor with your fingertips or hands). Now return to the starting position, standing erect with your hands above your head.

Mental task. Assume the starting position. Form as clear and vivid a mental image as possible of the movement just performed. Now rate the ease/difficulty with which you were able to do this mental task.

Participants rated the ease/difficulty with which they were able to do the nine imagery tasks on a scale ranging from 1 (*very easy to see/feel*) to 7 (*very hard to see/feel*); therefore, scores range from 9 to 63.

The original MIQ was used as opposed to revised shorter versions because of the wider range of imagery tasks covering more movements that feature to some extent in the execution of the tumble turn. The reliability of the MIQ is acceptable, with α values of .89 for the visual subscale and .88 for the kinaesthetic subscale (Hall et al., 1998). Therefore, the MIQ is an acceptable test to assess an individual's movement imagery ability.

Pre- and post-test tumble-turn performances were assessed by four national swimming coaches using assessment criteria developed by the coaches in conjunction with the first author. The criteria were as follows: Approach to turn (3 composite scores), rotation of the turn (4 composite scores), foot plant (2 composite scores), and transition into stroke (3 composite scores). Turn performance was rated on a scale ranging from 1 (*very poor*) to 5 (*very good*).

Procedure

Beedie and Lane (2012) highlight the importance of taking task meaning into account in self-control research. They argued that decrements in performance in the second task could be due to low motivation. Consequently, the recruitment strategy was to include participants with good intentions to learn the skills used in the current study. Participants were recruited to the current study via posters placed around University campus' requesting volunteers who wished to learn how to perform a front crawl tumble turn. This helped to ensure participants were recruited for whom the self-control task was meaningful. Participants were assigned to one of two conditions, a self-control condition (imagery) or a control (no-imagery) condition. Participants were matched for gender and swimming ability. An acknowledged limitation of the study is the relatively small sample size. Before collection of pre-test data, imagery-condition participants completed the MIQ (Hall & Pongrac, 1983) to screen for and exclude individuals with high imagery ability while also ensuring that participants could generate images, as indicated by MIQ scores less than 18, an arbitrary criterion selected by using the descriptors on the MIQ to gauge ease of imagery use. A score of 18 or less would indicate imagery was easy to do; therefore, it would not be acting as a self-control task because the task was well learned. No exclusions were made on the basis of MIQ data.

All participants were then introduced to the front crawl tumble turn. A competent swimmer demonstrated the front crawl tumble turn. A qualified swimming instructor highlighted the key technical aspects of the turn verbally. Participants then completed two 1-hr training sessions undertaken over 1 week to practice the tumble turn. After completion of these two sessions, pre-test data were collected. During the pre-test, each participant was filmed completing 10 tumble turns. It should be noted that filming performance is a method used to increase stress in experimental research (Wilson, Smith, & Holmes, 2007), and although we observed no indications of stress, this aspect of the research design is relevant because it served to maintain the importance of performance.

All participants then completed the same physical training program designed to enhance tumble turn performance. This comprised two 30-min training sessions per week for 5 weeks. Participants were provided with immediate feedback throughout training from a qualified swimming instructor to facilitate error correction.

Imagery-condition participants were provided with an imagery script that included both visual and kinaesthetic elements of the front crawl tumble turn. The following illustrative sentence from the script describes the initial stages in the execution of a tumble turn:

> Feel/see your dominant arm, which is outstretched in front of you sweep across your body; first downward through the water, then inwards and upwards toward your body. While you are pulling down through the water with your dominant hand feel/see your head simultaneously drive downward.

Participants were instructed to use the imagery script and verbal feedback provided to imagine performing the tumble turn correctly before each execution of the turn. Therefore, for imagery-condition participants, the sequence of events was as follows: perform imagery, perform skill, receive feedback, perform imagery, perform skill, and so on (see Table 1). This approach was intended to help participants generate personalised images of the front crawl tumble turn by incorporating modifications to imagery content on the basis of individual performance feedback. This facilitated usage of imagery that met each participant's stage of skill acquisition and learning needs. On completion of the fifth week of training, a post-test was complete in which a further 10 tumble turns were recorded.

Table 1

The Sequential Task Design

	Self-Control Group (Imagery)	Control Group
Task 1	Participants instructed to imagine performing a tumble turn correctly before physical execution of the turn.	
Task 2	Participants asked to perform a tumble turn.	
	All participants provided with verbal coaching to facilitate improvements during the next execution of tumble turn. The self-control group repeats the cycle of imagery followed by physical execution. The control group proceed to physical execution.	

During their research examining the effects of a short-term (45-min) imagery intervention, Wright and Smith (2007), suggest that imagery interventions require a higher level of functional equivalence when being used over a short period of time. The present study attained high levels of functional equivalence because imagery took place in a swimming pool, surrounded by the relevant sounds and smells, with participants wearing swimming attire. Furthermore, the imagery scripts and performance feedback provided to support imagery use were bespoke, taking into account personal learning. Participants in the imagery condition completed an imagery diary that acted as a manipulation check on whether participants engaged with the intervention; it also gave an insight into participant's experiences with the imagery intervention.

Assessors (four national swimming coaches) rated 19 pre- and post-test tumble turns, comprising 18 participants' best performances derived from pre- and post-test data, and also a duplicate turn (the exact same turn presented on two occasions). To control for possible expectations of improved performance across pre- and post-test, we presented the data in a randomised order. The coaches discussed each performance before reaching a consensus as to each participant's score. Agreement on each score was reached without dissent for all performances assessed, including the duplicate performance, for which an identical test-retest score was recorded.

Results

Inspection of participants' imagery diaries revealed that all participants reported performing imagery before physical execution of the tumble turn as instructed. All participants also perceived imagery to be helpful in learning how to tumble turn. The following illustrative extracts taken from imagery diaries detail the benefits and challenges as perceived by participants. One participant felt that "it helped me to focus on the turn and particularly areas of weakness, remembering the component parts of the skill." A different participant reported "it allowed me to rehearse the turn establishing a vivid mental picture of the actions. But it was difficult to transfer the images to real life." A further participant observed that "it helped to see the turn, but I could not imagine the feelings of buoyancy in the water, and my images were slower than the actual turn."

Using the descriptors on the Likert scale of the MIQ as a guide to interpreting how vividly participants could use imagery, results of the MIQ visual scale (M = 21.89, SD = 8.23) and MIQ kinaesthetic scale (M = 22.78, SD = 10.20) indicated that participants found imagery to be neither very easy nor very hard to do. Diary data indicated that all participants in the imagery condition actively used motor imagery before performance; hence, data from all participants went forward for further analysis.

Table 2 presents the descriptive statistics and confidence intervals for pre- and post-test tumble-turn performance scores by condition. Results indicate that performance improved in each group, as might be expected among a group of novice swimmers receiving coaching. However, repeated-measures multiple analyses of variance revealed significant improvements on all performance criteria within conditions, Wilks's lambda [4,13] = .39, $p < .05$, $\eta^2 = .61$, with no significant between-condition differences, Wilks's lambda [4,13] = .62, $p > .05$, $\eta^2 = .38$, and no significant interaction effect, Wilks's lambda [4,13] = .20, $p > .05$, $\eta^2 = .20$. The absence of a significant interaction effect indicates that the intervention condition did not improve faster than the control condition.

Table 2

Descriptive Statistics for Pre- and Post-test Tumble-Turn Performance Scores by Condition

	Imagery Condition			Control Condition		
	M	*SD*	95% CI	*M*	*SD*	95% CI
Approach to turn pre-test	8.32	2.51	[6.56, 10.08]	8.34	2.78	[6.37, 10.31]
Approach to turn post-test	9.40	2.79	[7.71, 11.09]	10.34	2.14	[8.45, 12.23]
Spin through turn pre-test	9.47	4.08	[6.84, 12.10]	10.31	3.71	[7.37, 13.25]
Spin through turn Post-test	10.72	2.73	[8.41, 13.03]	11.93	4.18	[9.35, 14.50]
Plant of feet on wall Pre-test	4.23	2.13	[2.96, 5.50]	3.23	1.56	[1.80, 4.65]
Plant of feet on wall Post-test	5.28	1.93	[3.92, 6.64]	5.53	2.16	[4.00, 7.05]
Transition into stroke Pre-test	8.69	2.94	[6.80, 10.58]	7.06	2.52	[4.99, 9.13]
Transition into stroke Post-test	7.22	2.76	[5.37, 9.07]	9.23	2.89	[7.11, 11.34]

Note. Approach to turn (3 composite scores), rotation of the turn (4 composite scores), foot plant (2 composite scores), and transition into stroke (3 composite scores). Turn performance was rated on a scale ranging from 1 (*very poor*) to 5 (*very good*). CI = confidence interval.

Discussion

The present study investigated the effects of imagery training on the performance of a swimming tumble turn and examined results in relation to two contrasting areas of literature, imagery research and self-control. We used a sequential-task design, commonly used in self-control studies, in which imagery acted as an act of self-control. In accordance with the imagery literature (Wakefield et al., 2013), improved performance was hypothesised. However, studies using a sequential-task design typically report worse performance after acts of self-control, and so it was also plausible that the control condition might improve at a faster rate (Baumeister et al., 2007; Hagger et al., 2010). Interaction results showing no significant effects (see Table 2) refute both explanations. Further, results show that post-test performance improved significantly among participants from both conditions.

The finding that teaching novice athletes to use imagery might not lead to enhanced performance (compared with no-imagery conditions) is not unique (Cumming & Williams, 2012, Nordin & Cumming, 2005). It is suggested that attempting to learn two new skills simultaneously does not *initially* bring about greater gains in performance. Self-control theory posits that learning skills discretely rather than sequentially could not only improve performance because of greater allocation of resources but also improve self-control strength. Self-control theory would suggest that imagery be learned away from the pool, rather than attempting to do imagery followed by a complex physical skill. It should be noted that many sport psychologists do this as routine practice.

The present study used a 5-week training programme between pre- and post-test performance, and therefore greater performance gains might be evidenced in longer programmes. On the basis of the present findings, we suggest that practitioners should counsel participants when introducing new psychological skills interventions to establish realistic performance expectations. Further, it might be advisable to teach new tasks in sequence. In other words, the introduction of imagery is possibly more suited to enhancing a task that is already well learned (Olsson & Nyberg, 2010) or, alternatively, develop imagery ability first before using it with the intention of aiding skill acquisition. A small to moderate amount of experience with a motor task may be sufficient to enhance the potential benefits to be accrued from motor imagery usage (Olsson & Nyberg, 2011). The benefits of these approaches are that participants may be better able to recreate the components of performance in detail and thus be able to develop more vivid, multisensory, and complete images (Guillot & Collet, 2005).

Regarding the second hypothesis, performance improved among the imagery condition in the current study, a finding that runs counter to proposals made in self-control theory (Baumeister, Vohs, & Tice, 2007; Hagger et al., 2010). Recent research has argued that motivation can offset the deleterious effects of self-control (Job, Dweck, & Walton, 2010), a finding consistent with results from the current study. Participants explicitly noted that they volunteered their time and involvement as they wished to learn how to perform a front crawl tumble turn, a behavioural indication of motivation. As such it is quite plausible that they maintained their motivation to perform to the best of their ability, and this enabled participants to override the potentially deleterious effects of self-control. Beedie and Lane (2012) argued that a limitation of research using the sequential-task design was that participants performed tasks of little personal meaning. Beedie and Lane challenged the notion that humans have fixed resources and argued that the evolved function of emotion was to increase energy, and so when performing a personally important task, emotions such as anxiety and excitement will generate arousal, and this can counter the effects of energy used in the first sequential task. The present study used a sample of volunteers interested in learning a new swimming skill, and video-recording performance acted as a further method to maintain the importance of engaging with the task.

The idea that teaching psychological skills requires acts of self-control and could be harmful to performance should be considered when developing psychological skills training programmes (Williams & Straub, 2010). Although the current study offers support for the notion that acts of self-control do not necessarily have negative effects on performance, the concept of self-control does offer a possible explanation for poor adherence to ongoing psychological skills usage. Shambrook and Bull (1999) noted that people often struggle to adhere to psychological skills training programmes; a finding that alludes to the possibility that the process is effortful and so might not lead to immediate benefits. Athletes may perceive effort invested as producing insufficient benefits, a possibility that again reinforces the value of counselling athletes to ensure that their outcome expectancies are realistic, particularly during the early stages of psychological skills training.

The present study brings together two distinct bodies of research that typically might operate in silos. Drawing synergies between distinct literatures has allowed examination of competing hypotheses. It has also enabled alternative explanations for poor adherence to psychological skills training to be proposed. Self-control is a well-established area of research inquiry within general psychology, and although its application to sport and exercise contexts is in its infancy, it holds great promise in better understanding human performance and the process of behaviour change. We suggest that future research should investigate the processes through which people learn psychological skills, in particular the role of self-control. In doing so research should examine the timing of imagery use, specifically contrasting the effects of motor imagery use independent of and immediately before motor execution.

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